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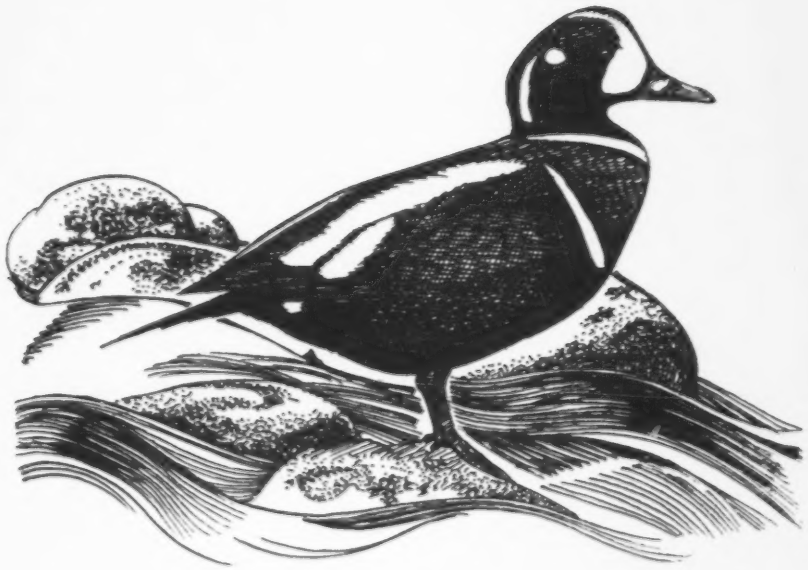
Harlequin Duck Monitoring in the Northern East Slopes of Alberta: 1998-2000 Preliminary Results

Jeff Kneteman and Anne Hubbs



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HARLEQUIN DUCK MONITORING IN THE NORTHEASTERN SLOPES OF ALBERTA: 1998-2000; PRELIMINARY RESULTS

October 2000 Jeff Kneteman and Anne Hubbs

ABSTRACT

Aerial surveys for harlequin ducks (*Histrionicus histrionicus*) were conducted in the spring of 1998-2000 in the McLeod and Cardinal River watersheds, and in 10 watersheds in the Willmore Wilderness Park. Ground and aerial surveys of broods occurred in August and September 2000, respectively along the Sulphur and Berland Rivers. The objectives of the surveys were 1) to assess the utility of aerial surveys in censusing harlequin duck populations, and 2) to determine presence, relative abundance, population trends, distribution, and productivity of harlequin ducks in selected watersheds. Visibility from the air was approximately $\geq$ 70% that from the ground during spring surveys of the McLeod watershed in 1998 and 2000 compared with only 13-27% in 1999 when lighting conditions were poor. These results indicate that aerial surveys can be an effective method of censusing harlequin ducks when lighting conditions are favourable. Spring numbers were relatively high in the McLeod-Whitehorse, Berland, and Sulphur watersheds (approximately $\geq$ 40 birds) followed by the Muskeg, Sheep-Cote, Muddywater-Fetherstonhaugh, and Jackpine watersheds (approximately $\geq$ 15 birds). Relatively few birds were observed on the Smoky, Cardinal, Little Berland, Wildhay Rivers, and Hardscrabble Creek (< 15 birds). When watersheds were flown in more than one year, the number and distribution of birds were consistent across years for all watersheds except the Muskeg River in which 15 more birds were seen in 1998 (23) than in 2000 (8). During ground surveys in August 2000, two broods with 5 young each were observed on the West and South Sulphur Rivers. Four broods (three with 7 young, one with four young) were recorded on the South and North Berland Rivers. During aerial surveys in September 2000, four broods (all with 4 young) were observed on the Sulphur River and five broods (total of 22 young) were observed on the Berland Rivers. Unlike ground surveys, aerial surveys included the mainstems of these rivers. Based on aerial survey results, 18% of females observed in the spring produced broods on the Sulphur River compared with 23% on the Berland River. Female reproductive output (number of ducklings per number of females observed in spring) was 0.73 and 1.00 for the Sulphur and Berland watersheds, respectively. Productivity in these watersheds was, on average, lower than that reported for the McLeod-Whitehorse watershed and the Kananaskis and Elbow Rivers in Kananaskis Country, but was higher than on the Bow River in Banff National Park.

INTRODUCTION

The harlequin duck is a relatively rare seaduck that breeds and nests in low densities in fast-flowing mountain streams. Like other seaducks, it is characterized by low productivity, delayed breeding, and a long lifespan (Goudie et al. 1994). As a result, even low levels of human-induced mortality or reduced productivity may have serious negative effects on populations. The well-being of harlequin ducks is dependent upon water clarity, non-polluted

waters with abundant macroinvertebrate populations and possibly relatively undisturbed native habitat for nesting. Potential factors that have lead to population declines and endangered species status of eastern populations include destruction and degradation of habitats from forestry and resource extraction industries, and disturbance from recreational activities (Montevecchi et al. 1995). Population declines have also been reported for western populations (Robertson and Goudie 1999). Harlequin ducks are a species of concern requiring special management attention in Oregon, Washington, Montana, Idaho, Wyoming, British Columbia, and Alberta. Harlequin ducks are classified as Yellow "A" in Alberta because of long-term declines and restricted distribution (The Status of Alberta Wildlife 1996).

In the eastern slopes region of Alberta, knowledge on population sizes, productivity, and distribution of this species is limited. Biological and ecological research has occurred primarily in national and provincial parks to assist assessment of recreation and road development influences (Jasper, Banff, Peter Lougheed, Kananaskis Country- Hunt 1998, Smith 1998, 1999, 2000a,b). Outside parks, Cardinal River Coals Ltd. (CRC) has sponsored monitoring in the McLeod and Cardinal River watersheds from 1995-2000 to examine population demographics, and response to mining activity (MacCallum 1997; MacCallum and Bugera 1998; MacCallum et al. 1999; MacCallum and Godsalve 2000). Mining proposals include pit, dump and road development, culvert installation and stream diversion and infill in the upper McLeod River watershed. Research and monitoring on harlequin ducks has involved instream (ground) surveys, banding, radio-telemetry, and behavioral observations.

Ground surveys can be time-consuming, expensive, difficult in remote areas and can require substantial manpower to complete data collection within the short period of each reproductive life stage of the harlequin duck, particularly if multiple streams are to be assessed. Aerial surveys to assess spring presence of adults were conducted in the central and northern eastern slopes of Alberta, outside of the National Parks, in 1998 and 1999 (Gregoire et.al.,1999, Gregoire 2000). Surveys identified harlequin duck distribution as patchy, at low densities with concentrations in the Willmore Wilderness Park area (≥200 ducks), approximately 40% of observations were on the Berland and Sulphur Rivers; in the upper McLeod River watershed (≥ 70 ducks)(see also MacCallum 1999 and MacCallum and Godsalve 2000) and the upper North Saskatchewan Drainage (≥ 60 ducks), with populations predominately occurring in the Blackstone-Wapiabi (≥30 ducks), North Ram (≥ 15 ducks) and Cardinal (< 15 ducks) Rivers. The Bow-Kananaskis-Elbow Rivers complex (≥200 ducks) (Smith 2000a,b) is the only reported population concentration in southern Alberta. Small numbers (typically 1-5) of harlequin ducks have been reported in a number (≥200) of mountain and foothill streams (Alberta Environment in prep.). Ducks that are observed throughout the year on smaller streams or in smaller populations are not necessarily independent of numbers that are observed on streams of known spring concentration. The upper McLeod River supports the highest reported single stream population and concentration in Alberta, other than the Bow River in Banff National Park.

From 1998-2000, Alberta Environment and the Canadian Wildlife Service (CWS) conducted aerial surveys of the Mcleod and Cardinal River watersheds and selected streams within the Willmore Wilderness Park area. In addition, ground surveys for broods were initiated in 2000 on the Sulphur and Berland Rivers by Alberta Environment. The objectives of these surveys were 1) to assess the utility of aerial surveys in censusing harlequin

duck populations, and 2) to determine presence, relative abundance, population trends, distribution, and productivity of harlequin ducks in selected watersheds.

METHODS

Spring surveys were conducted in late May-early June during the early breeding season, when adults are concentrated on main river stems, on 19 rivers comprising 12 watersheds (Table 1). Sixteen of the river sections surveyed were located within Willmore Wilderness Park. The remaining three rivers (McLeod, Cardinal and Whitehorse Creek) were situated in the Coal Branch Region near Cadomin townsite and approximately 50-70 km south of Hinton. The McLeod River and Whitehorse Creek were flown every year on one of the days that CRC conducted ground surveys over a 2-3 day period. In total, the number of watersheds surveyed each year was 6 in both 1998 and 1999, and 8 in 2000 (Appendix, Figs 1-3). Five watersheds (Cardinal, Little Berland, Hardscrabble, Smoky, Jackpine) were surveyed only once from 1998-2000 (Table 1). The remaining 6 watersheds (excluding McLeod-Whitehorse) were surveyed every second year (Table 1). The total number of hours flown in the spring was 11.9, 15.5 and 11.7 in 1998, 1999, and 2000, respectively.

Brood surveys were flown on September 8, 2000 on the West and South Sulphur Rivers, and the South and North Berland Rivers (total of 3.7 hrs).

A Bell 206B Jet Ranger helicopter was flown approximately 30m above the water at an average speed of 55 km/hr. Streams were flown primarily in an upstream direction, although occasionally streams were flown in a downstream direction to minimize flying hours. Streams were flown until the headwaters were reached or vegetation and channel constriction markedly obscured visibility. The left front passenger was responsible for navigating and observing while the rear right passenger observed and recorded onto field data sheets. Global Positioning System (GPS) locations were recorded for start and end survey points and for all duck observations. In addition, the number of ducks and group composition (pairs, single male or female, ducklings with or without a female) was noted. Flights were conducted between 10:00-16:00 when viewing conditions were generally most favourable, except on the McLeod-Whitehorse survey in 1999.

Instream brood surveys occurred between August 8-10, 2000 on the West and South Sulphur Rivers, and the South and North Berland Rivers (4.0 helicopter hours, 20 mandays). Two and 3 people surveyed the Berland Rivers and Sulphur Rivers respectively by walking instream or on the immediate shoreline. Birds were either identified using the naked eye or with the aid of 8 x 40 binoculars. GPS locations were recorded for start and end survey points and all duck observations. The number of ducks and group composition (single female, female with ducklings, ducklings alone) was noted.

RESULTS

Visibility

Two estimates of visibility from the air were calculated by comparing aerial and ground survey results on the McLeod-Whitehorse watershed. The first estimate used the percentage of total birds observed from the air divided

by the number seen from the ground. Visibility from the air was approximately ≥ 70% that from the ground during spring surveys of the McLeod-Whitehorse watershed in 1998 and 2000 compared with only 13-27% in 1999 (Table 2). Moreover, 6-7 more ducks were observed on Whitehorse Creek from the air than from the ground in 2000 (Table 2). Visibility did not differ between males and females in any consistent pattern. The 1st ground survey of the McLeod-Whitehorse in 2000 was conducted simultaneously with the aerial survey. Aerial visibility on that portion of the aerial survey length corresponding to the ground survey represented 83%, 300% and 96% of ground observations on the McLeod, Whitehorse and McLeod-Whitehorse respectively. Observations from the lengthier total aerial survey section (Table 3) represented 114% and 95% of observations from the 1st and 2nd ground surveys (Table 2) respectively of the McLeod-Whitehorse watershed.

The second estimate used the percentage of birds observed from the air divided by an estimate of population size from ground mark-resighting data. Fifty one percent and 25% of the mark-resight estimated population was observed from the air in the McLeod-Whitehorse watershed in 1998 and 1999, respectively (Table 2). Mark-resight population estimates are not yet available for 2000. Mark-resight population estimates also included ducks observed on the Luscar, Drummond Creek, Harlequin, Prospect, Cheviot, Unnamed "J", Harris, and Thorton Creeks.

It was not possible to obtain an estimate of visibility from brood surveys. Aerial surveys occurred approximately one month after ground surveys and some birds may have died or migrated during the intervening period. However, aerial surveys located 7 broods (Sept. 8) on stream sections where ground surveys located 6 broods (Aug. 8-10) (Table 4).

Spring Numbers and Distribution

Spring numbers (Table 3) were relatively high in the McLeod-Whitehorse, Berland, and Sulphur watersheds (approximately ≥ 40 birds) followed by the Muskeg, Sheep-Cote, Muddywater-Fetherstonhaugh, and Jackpine watersheds (approximately ≥ 15 birds). Relatively few birds were observed on the Smoky, Cardinal, Little Berland, Wildhay Rivers, and Hardscrabble Creek (< 15 birds). When watersheds were flown in more than one year, the number of birds was consistent across years for all watersheds except the Muskeg River in which 15 more birds were seen in 1998 (23) than in 2000 (8). Fewer birds were also seen in 1999 than 1998 or 2000 on the McLeod-Whitehorse watershed. In general, sex ratios were male biased and pairs comprised 57-100% of the birds seen on a specific stream (excluding 4 stream sections where 0 or 1 duck was seen). Pairs represented ≥70%, ≥80% and ≥90% of ducks observed on 92.5%, 62.5% and 12.5% respectively of surveyed streams where more than 1 duck was observed.

The distribution of ducks in each watershed is shown for each year in figures 4 - 16 (see Appendix). The distribution of ducks was generally clumped within a river and was consistent across years for most watersheds surveyed in more than one year (Figs 10, 13, 17 - 20, Appendix). On the McLeod River, the greatest concentration of ducks occurred downstream of Whitehorse Creek in all years. Similarly, most ducks were observed in the downstream stretch (below Harlequin Creek) on Whitehorse Creek in 1998-2000. Ducks were also concentrated in downstream stretches on the south and north Berland Rivers, the Muskeg River (near a la Peche Lake area), and the mainstem of the Sulphur River in all years surveyed. In contrast, ducks were distributed along the entire survey

length on the West Sulphur River. On the Wildhay most observations occurred between Seep and Eagle Nest Creeks. The distribution pattern was similarly clumped across all years on the Sheep-Cote and the Muddywater-Fetherstonhaugh watersheds.

Brood surveys

The results of aerial and ground brood surveys are shown in Table 4. During ground surveys in August 2000, two broods with 5 young each were observed on the West and South Sulphur Rivers. Four broods (three with 7 young, one with four young) were recorded on the South and North Berland Rivers. During aerial surveys in September 2000, four broods (all with 4 young) were observed on the Sulphur River and five broods (total of 22 young) were observed on the Berland Rivers. Unlike ground surveys, aerial surveys included the mainstems of these rivers. The distribution of broods during aerial and ground surveys is shown in figures 21 - 24 (see Appendix).

Productivity was estimated using the number of females observed in the spring, rather than the number of pairs because females are a limiting sex and it is not always possible to assess pair status from the air. This methodology has also been employed by Smith (2000a,b) for Banff National Park and Kananaskis Country. Based on aerial survey results (Table 5), 18% of females observed in the spring produced broods on the Sulphur River compared with 23% on the Berland River. Female reproductive output (number of ducklings per number of females observed in spring) was 0.73 and 1.00 for the Sulphur and Berland watersheds, respectively. Productivity in these watersheds was, on average, lower than that reported for the McLeod-Whitehorse watershed and the Kananaskis and Elbow Rivers in Kananaskis Country, but was higher than on the Bow River in Banff National Park (Table 5).

DISCUSSION

The results of this investigation indicate that aerial surveys can be an effective method of censusing harlequin ducks. Visibility from the air was approximately $\geq$ 70% that from the ground during spring surveys of the McLeod-Whitehorse watershed in 1998 and 2000 (Table 2). Moreover, 6-7 more ducks were also observed on Whitehorse Creek from the air than from the ground in 2000 (Table 2). There was also consistency between years in the number of ducks recorded on most streams that were flown in multiple years in Willmore Wilderness Park (Table 3). In the future, it is proposed to fly streams more than once within a given reproductive stage of the ducks (e.g. breeding, post-hatching, pre-migration) to determine within-year variance associated with aerial survey results and to obtain population estimates. If this variance is low after only a few flights, aerial surveys will be a more time and cost effective method of censusing harlequin ducks than ground surveys, even on easily accessible streams. A ground survey of the road accessible McLeod-Whitehorse watershed required 2-3 days to complete with 3 people/day (without banding birds and associated costs and time) compared with 1.9 hrs to fly the lengthier aerial survey section. A duck is also less likely to be counted more than once in a single aerial than ground survey because harlequin ducks rarely fly in front of the helicopter and observers can follow the path of flying ducks. Harlequin ducks respond to helicopters by moving to stream centers, wing flapping and diving with immediate resurfacing, rendering them highly visible to observers. Aerial surveys can also be performed in locations where ground surveys are difficult because of strong water currents, dense vegetation, or manpower costs are high to reach remote streams.

Also, given that aerial surveys can include the entire watercourse, the issue of closure that is assumed when estimating population size from mark-resighting data can be overcome. Aerial surveys of the McLeod River have indicated that ducks occur outside of the area surveyed from the ground and thus, population estimates from ground surveys may violate the closure assumption. In 1998, 1999 and 2000 2, 5 and 9 ducks respectively (4%, 8%, 16-19% of ground counts) (table 2&3) were observed by aerial surveys outside of ground survey sections.

Aerial surveys are effective provided the stream has a wide enough channel for the helicopter to fly below tree height or provided a narrow channel is not treed to the water edge. Aerial surveys were attempted in 1999 on the Gregg River and Drinnan Creek, but no ducks were observed possibly because narrow channels with trees to the channel edge obscured visibility. Flat lighting conditions are also preferred for surveying from the air because bright lighting may make it difficult to distinguish ducks from background. Visibility from the air was only 13-27% in 1999 on the McLeod-Whitehorse watershed (Table 2) when lighting conditions were bright.

Aerial census requires more rigorous testing of precision. However, initial results are promising that harlequin duck censusing can substantially be expanded in geographic scope and stream specific continuity and intensity. When assessing the relative costs of aerial versus ground survey the costs of marking (banding or radio-telemetry) birds may or may not be a significant consideration. Aerial census appears suitable for determining population size estimates, adult sex composition, course (stream by stream) and fine (stream section) scale distribution and annual reproductive rate. When ground surveys using marked birds provides just the same information that aerial surveys provide, the cost of marking should be considered in the cost assessment. Costs of marking may not be a significant additional cost of ground surveys when individual identification of birds by ground surveys provides substantive determination of population parameters not discernable by aerial surveys. Such parameters include annual survival, longevity, annual rate of return, fidelity to stream or stream section, age of first reproduction, frequency of reproduction, between year variability in individual productivity or lifetime reproductive output.

The number of harlequin ducks in the spring (Table 3) was relatively high in the McLeod-Whitehorse, Berland, and Sulphur watersheds (approximately $\geq$ 40 birds) followed by the Muskeg, Sheep-Cote, Muddywater-Fetherstonhaugh, and Jackpine watersheds (approximately $\geq$ 15 birds). Relatively few birds were observed on the Smoky, Cardinal, Little Berland, Wildhay Rivers, and Hardscrabble Creek (< 15 birds). In comparison, the highest number of ducks observed during instream surveys on the Bow River in Banff National Park from 1995-99 was 132 (77 males, 55 females) for a density of 4.3 ducks per km (Smith 2000a). Population estimates from mark-resighting data ranged from 111-157 ducks from 1995-99 on the Bow River (Smith 2000a) compared with an estimated 78.5 $\pm$ 6.8 sd and 68.0 $\pm$ 2 sd in the McLeod-Whitehorse watershed in 1998 and 1999, respectively (MacCallum et al. 1999; MacCallum and Godsalve 2000). Population estimates were higher for the McLeod-Whitehorse watershed than the Elbow and Kananaskis Rivers in Kananaskis Country (12-28 and 41-43 ducks, respectively; Smith 2000b). In the future, population size should be estimated for watersheds in Willmore Wilderness Park by flying streams more than once within a year. Density estimates will also be available for existing data once survey distances have been determined using the WAM / HAGIS model. Density will be determined using first, total survey length and second, distance from the first to last duck. Density estimated using total survey length will be biased by where surveys

began and ended, but will provide an overall estimate for a given watershed. By instead measuring survey length from the first to last duck, density will be estimated for a greater proportion of suitable harlequin duck habitat.

The distribution of ducks was patchily distributed within a river and was consistent across years for most watersheds surveyed in more than one year (Figs 10, 13, 17 - 20, Appendix). A patchy distribution in conjunction with low densities, restricted use of habitats, and low productivity support the classification of harlequin ducks as a sensitive species requiring special management considerations. Smith (2000a) made a series of recommendations for managing harlequin ducks in the Bow River system and some of these could be applied to the McLeod-Whitehorse watershed and streams in Willmore Wilderness Park. General recommendations include monitoring the macroinvertebrate prey base, determining breeding status of streams that are listed as probable or unknown, and establishing criteria for the construction and design of bridges and culverts in streams with harlequins. Further research in the McLeod-Whitehorse watershed and Willmore Wilderness Park could include an assessment of stream characteristics at duck observation sites using the WAM / HAGIS model and additional surveying of smaller streams. It is possible that changes in population size would occur first in these small tributaries of lower quality habitat rather than in larger higher quality rivers. However, small streams used by harlequin duck for nesting or brooding are expected to support 1-2 pairs making assessment of change difficult.

Based on aerial survey results, 18% of females observed in the spring produced broods on the Sulphur River compared with 23% on the Berland River. Female reproductive output was 0.73 and 1.00 for the Sulphur and Berland watersheds, respectively. Productivity in these watersheds was, on average, lower than that reported for the McLeod-Whitehorse watershed and the Kananaskis and Elbow Rivers in Kananaskis Country, but was higher than on the Bow River in Banff National Park (Table 5). We propose that in the future, female productivity continue to be monitored in the McLeod-Whitehorse watershed and the Willmore Wilderness Park using current methods and consistent stream sections across years. If funding permits, an additional aerial survey in August may be included to estimate hatching success.

In summary, aerial surveys can be a time and cost effective alternative to ground surveying for censusing harlequin ducks. Population estimates from the McLeod-Whitehorse watershed were higher than those for the Elbow and Kananaskis Rivers in Kananaskis Country, but lower than for the Bow River in Banff National Park. Population size will be estimated in the future for watersheds in Willmore Wilderness Park. Productivity in the Sulphur and Berland River watersheds was, on average, higher than that reported for the Bow River, but lower than on the McLeod-Whitehorse watershed and Kananaskis Country.

RECOMMENDATIONS

The following recommendations are not listed in order of priority.

1) It is recommended that aerial surveys continue in the McLeod-Whitehorse watershed, the Cardinal River, and the 10 watersheds previously surveyed in Willmore Wilderness Park. These surveys should occur annually in the McLeod-Whitehorse watershed and every 2 or 3 years in the remaining watersheds. All surveys should use consistent stream sections across years.

2) Aerial surveys should occur during breeding and brooding periods (late May-early June and August-September) to determine relative abundance, population trends, distribution, and productivity. Additional aerial and ground surveys should be conducted in August approximately three weeks post-hatching to assess hatching success.

3) Within a given year, streams should be flown more than once during breeding and brooding periods to determine within-year variance associated with aerial survey results and to obtain population estimates. Should funding permit, multiple flights should also occur approximately three weeks after hatching.

4) Locations of observations from different replicates in the same survey sequence on the same survey section should be analysed for consistency of location and group size and composition to assist understanding of prevalence of missed birds.

5) Early September brood assessments on the McLeod-Whitehorse watershed are required to render productivity estimates comparable to results available from the Bow, Elbow and Kananaskis Rivers and the Willmore Wilderness Park area.

6) Further research in the McLeod-Whitehorse watershed and Willmore Wilderness Park should include an assessment of stream characteristics at duck observation sites using the WAM / HAGIS model and additional surveying of smaller streams in the future. It is possible that changes in population size would be evident first in these small tributaries of lower quality habitat rather than in larger higher quality rivers.

7) The raw data from ground surveys of the McLeod-Whitehorse watershed should be reviewed to determine the rate at which marked birds are observed more than once during the same survey on subsequent days or along different stream sections. If marked birds are recorded more than once in a survey, the number of unmarked birds should be adjusted by a similar ratio as well. This will affect the total number of ducks reported and subsequent population estimates.

8) Assessment and determination of whether there is significance to non-convergence of female breeding success estimates derived from radio-tagged females versus non-telemetry females, as noted by Smith (2000a, pg. 46) and detected in data presented by MacCallum and Godsalve (2000 pg.10 and 12, table 2) should be considered.

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APPENDIX

The following maps are in projection UTM 11 NAD 83.

Table 1 Watersheds surveyed in 1998-2000

Watershed	Streams	Year(s) Surveyed			Type of Survey	
		1998	1999	2000		
McLeod-Whitehorse	McLeod River	X	X	X	Aerial & Ground [1]	Spring
	Whitehorse Creek	X	X	X	Aerial & Ground [1]	Spring
Cardinal	Cardinal River	X			Aerial	Spring
Berland	Mainstem of Berland River	X		X	Aerial	Spring & Brood
	North Berland River	X		X	Aerial & Ground	Spring & Brood
	South Berland River	X		X	Aerial & Ground	Spring & Brood
Little Berland	Little Berland River	X			Aerial	Spring
Muskeg	Muskeg River	X		X	Aerial	Spring
Sulphur	Mainstem of Sulphur River	X		X	Aerial	Spring & Brood
	South Sulphur River	X		X	Aerial & Ground	Spring & Brood
	West Sulphur River	X		X	Aerial & Ground	Spring & Brood
Hardscrabble	Hardscrabble Creek			X	Aerial	Spring
Wildhay	Wildhay River		X	X	Aerial	Spring
Smoky	Smoky River		X		Aerial	Spring
Jackpine	Jackpine River		X		Aerial	Spring
Sheep-Cote	Sheep Creek		X	X	Aerial	Spring
	Cote Creek		X	X	Aerial	Spring
Muddywater-Fetherstonhaugh	Muddywater River		X	X	Aerial	Spring
	Fetherstonhaugh Creek		X		Aerial	Spring

[1] Ground surveys on the McLeod River and Whitehorse Creek were conducted by MacCallum et al.

Table 2 Comparison of Aerial & Ground Spring Survey Results in the McLeod Watershed, 1998-2000

Stream	Year	Type of Survey [1]	Total Count	% Visibility (aerial / ground totals)	% Visibility of Males	% Visibility of Females	% Population Visibility (aerial total / population estimator) [2]
McLeod River	1998	Aerial	35 (19 M, 16 F)	76%	73%	80%	N / A
		Ground	46 (26 M, 20 F)				
	1999	Aerial	16 (9 M, 7 F)	27%	28%	25%	N / A
		Ground	60 (32 M, 28 F)				
	2000	Aerial	38 (22 M, 16 F)	1st survey 83% 2nd survey 67%	1st survey 88% 2nd survey 79%	1st survey 76% 2nd survey 55%	N / A
		Ground	46 (25 M, 21 F)				
		Ground	57 (28 M, 29 F)				
Whitehorse Creek	1998	Aerial	5 (3 M, 2 F)	71%	75%	67%	N / A
		Ground	7 (4 M, 3 F)				
	1999	Aerial	1 (0 M, 1 F)	13%	0%	25%	N / A
		Ground	8 (4 M, 4 F)				
	2000	Aerial	9 (4 M, 5 F)	1st survey 300% 2nd survey 450%	1st survey 400% 2nd survey 400%	1st survey 250% 2nd survey 500%	N / A
		Ground	3 (1 M, 2 F)				
		Ground	2 (1 M, 1 F)				
Total McLeod-Whitehorse	1998	Aerial	40 (22 M, 18 F)	76%	73%	78%	51%
		Ground	53 (30 M, 23 F)				
	1999	Aerial	17 (9 M, 8 F)	25%	25%	25%	25%
		Ground	68 (36 M, 32 F)				
	2000	Aerial	47 (26 M, 21 F)	1st survey 96% 2nd survey 80%	1st survey 100% 2nd survey 90%	1st survey 91% 2nd survey 70%	N / A
		Ground	49 (26 M, 23 F)				
		Ground	59 (29 M, 30 F)				

[1] Ground surveys were conducted from May 27-28 and May 25-28 in 1998 and 1999, respectively. Two ground surveys were conducted in 2000 (May 23-24 and May 30-June 1). Aerial surveys occurred on May 24 or 25th in all years. For comparison purposes, stream sections were limited to that used in both aerial and ground surveys. Surveys were conducted from the CN bridge to near Mt. Park on the McLeod River, and from the confluence to the ford on Whitehorse Creek.

[2] Population estimates were determined from ground mark-resightings information collected from May 25-29. Population estimates 78.5 $\pm$ 6.8 sd and 68.0 $\pm$ 2 sd in 1998 and 1999, respectively (MacCallum 1999, 2000). Estimates are not yet available for 2000.

Table 5 Productivity of Female Harlequin Ducks in Selected Watersheds in the Northeast Slopes of Alberta

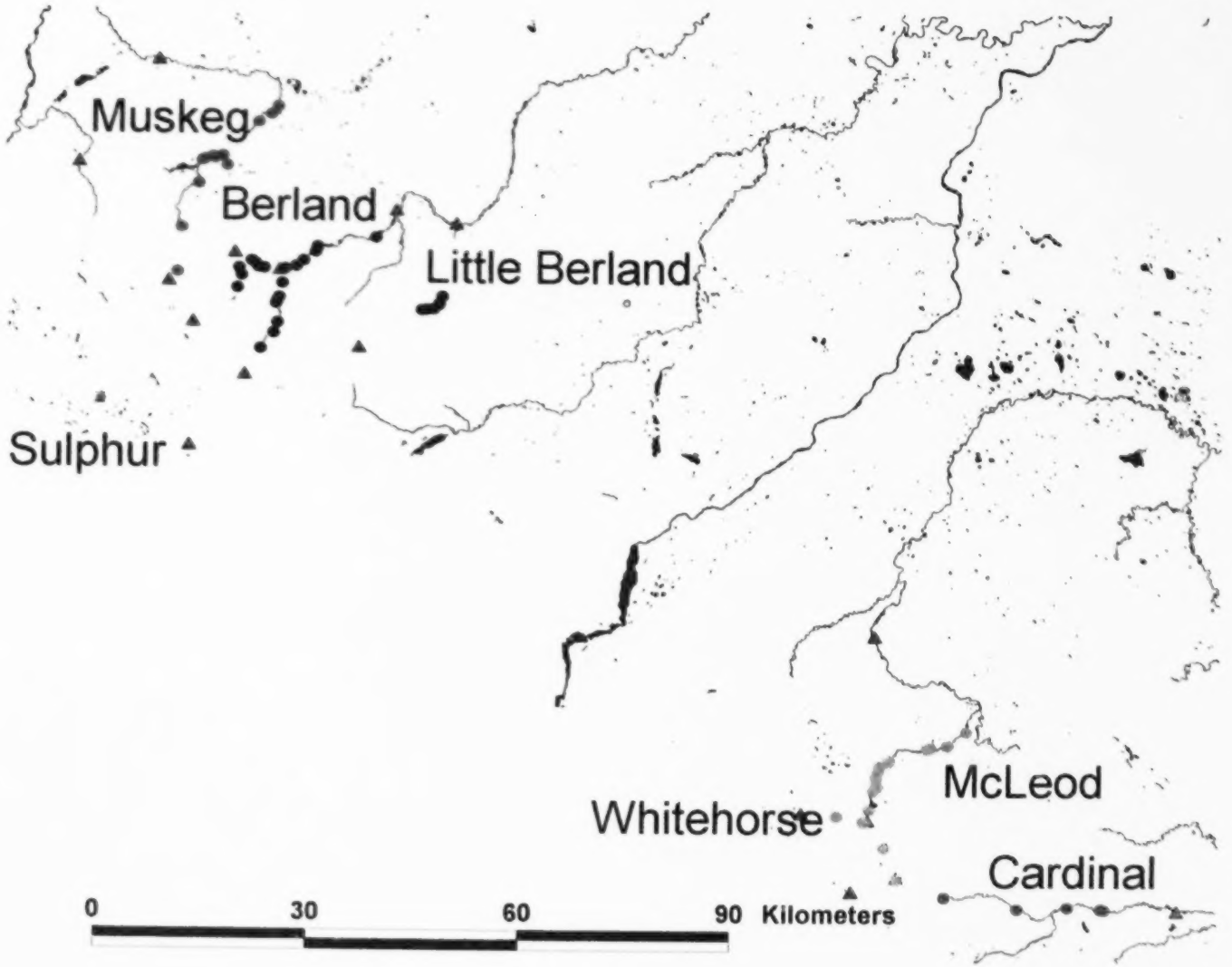
Watershed	Source	Type of Survey	Year	# of Females in Spring	# Broods in August or Sept.	# Broods / # Females in Spring (%)	# Ducklings	Ducklings / Female
Sulphur River, Willmore Park	This Report	Aerial	2000	22	4	18.2	16	0.73
Berland River, Willmore Park	This Report	Aerial	2000	22	5	22.7	22	1.00
McLeod-Whitehorse [1]	MacCallum 2000	Instream	1996	28	11	39.3	55	1.96
			1997	24	9	37.5	43	1.79
			1998	31	9	29.0	35	1.13
			1999	32	4	12.5	18	0.56
Bow River, Banff Park	Smith 2000a	Instream	1996	34	4	11.8	15	0.44
			1997	32	8	25.0	24	0.75
			1998	15	3	20.0	3	0.20
			1999	16	3	18.8	5	0.31
Kananaskis River, Kananaskis Country	Smith 2000b	Instream	1998	8	3	37.5	10	1.25
			1999	12	5	41.7	19	1.58
Elbow River, Kananaskis Country	Smith 2000b	Instream	1996	5	?	?	10	2.00
			1997	13	3	23.1	13	1.00
			1998	7	2	28.6	5	0.71
			1999	5	1	20.0	2	0.40

Averages								
Willmore Park						20.5 (18-23)		0.87 (0.7-1.0)
McLeod-Whitehorse						29.6 (13-39)		1.36 (0.6-2.0)
Banff Park						18.9 (12-25)		0.43 (0.4-0.8)
Kananaskis Country						30.2 (20-42)		1.16 (0.4-2.0)

[1] Includes Luscar, Drummond, Harlequin, Prospect, Cheviot, Harris, Thorton, and Unnamed "J" Creeks.

Appendix 1 - Harlequin duck spring surveys 1998

Harlequin duck spring surveys 1998

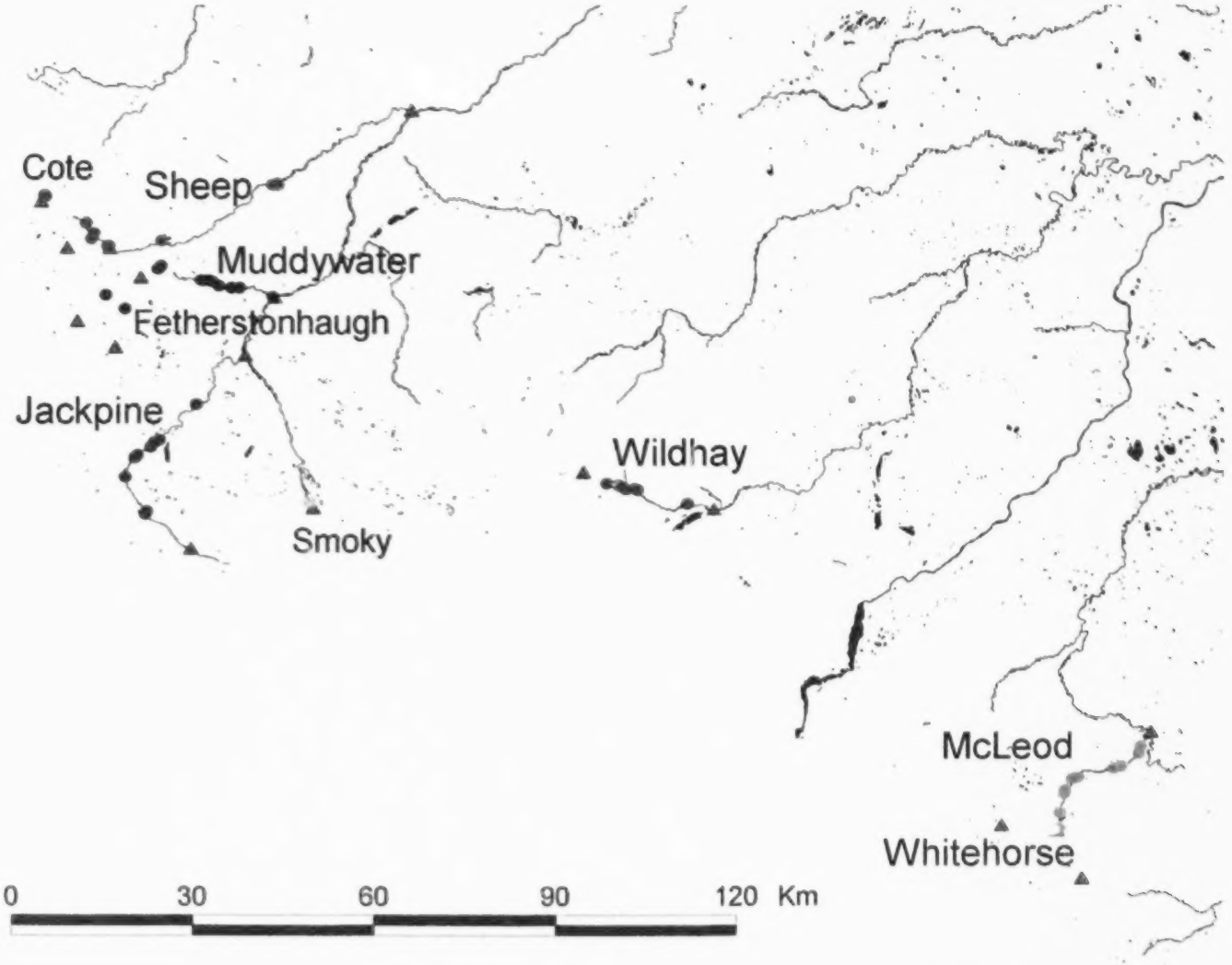


Alberta
ENVIRONMENT

N
W E
S

Appendix 2 - Harlequin duck spring surveys 1999

Harlequin duck spring surveys 1999

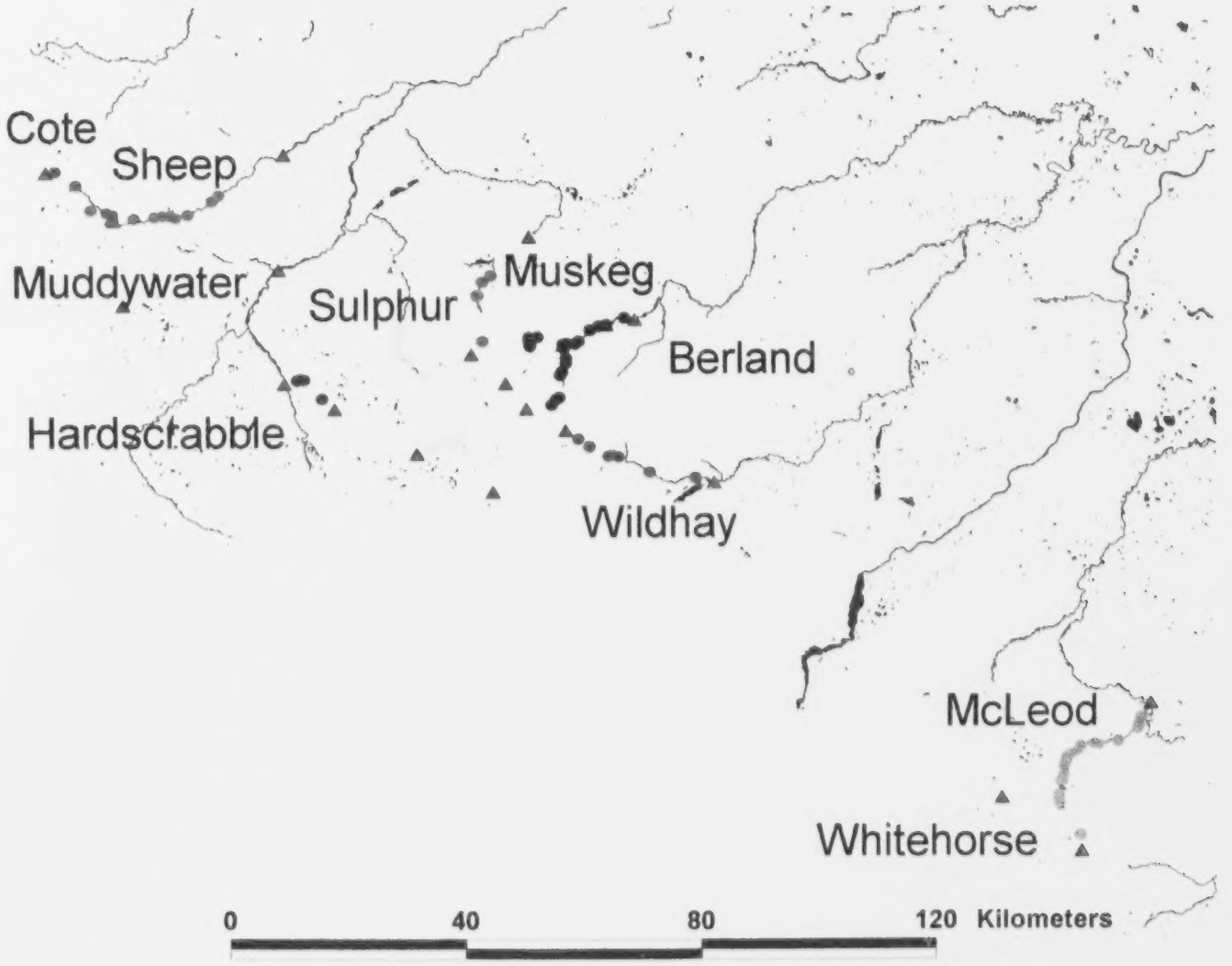


Alberta
ENVIRONMENT

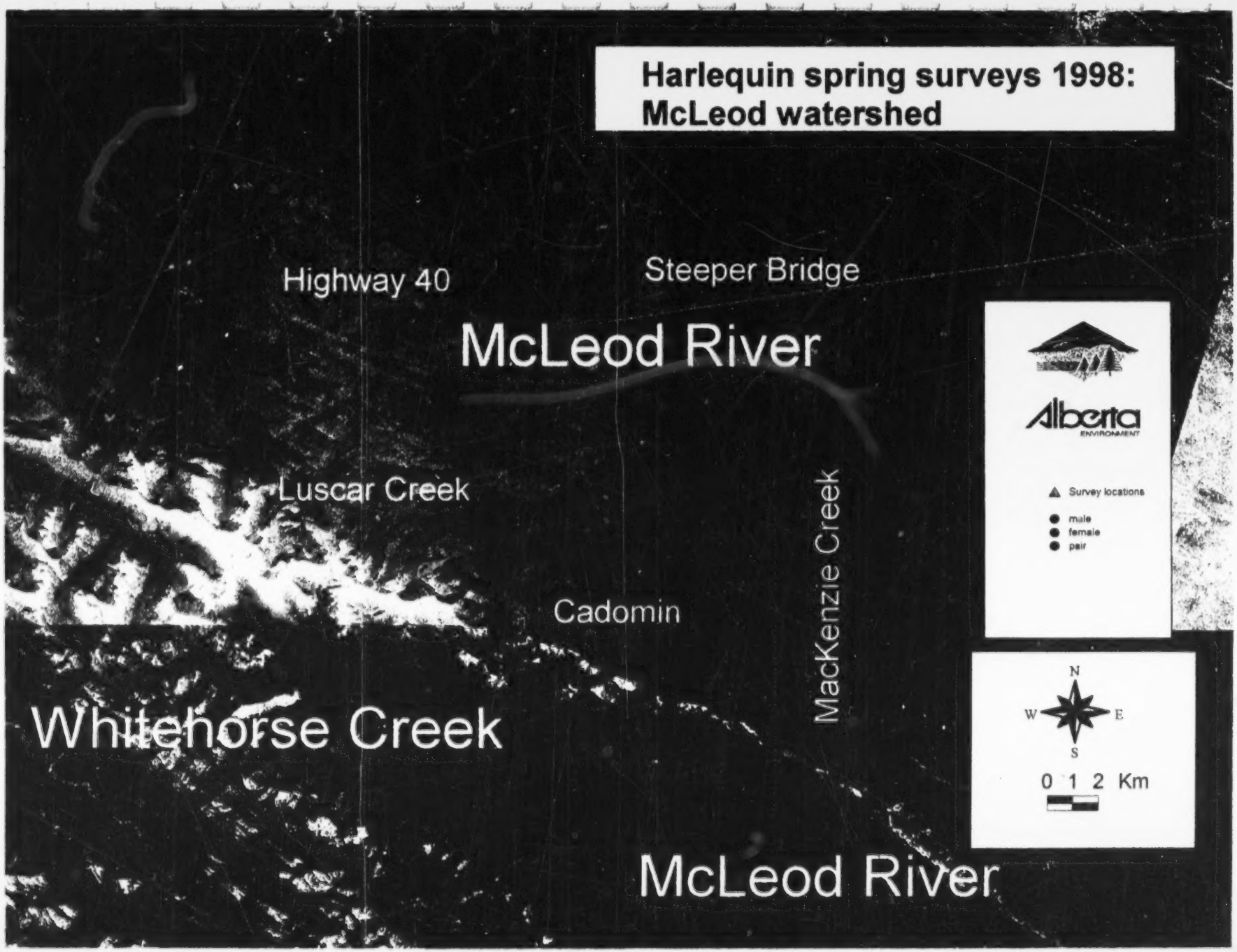
N
W
E
S

Appendix 3 - Harlequin duck spring surveys 2000

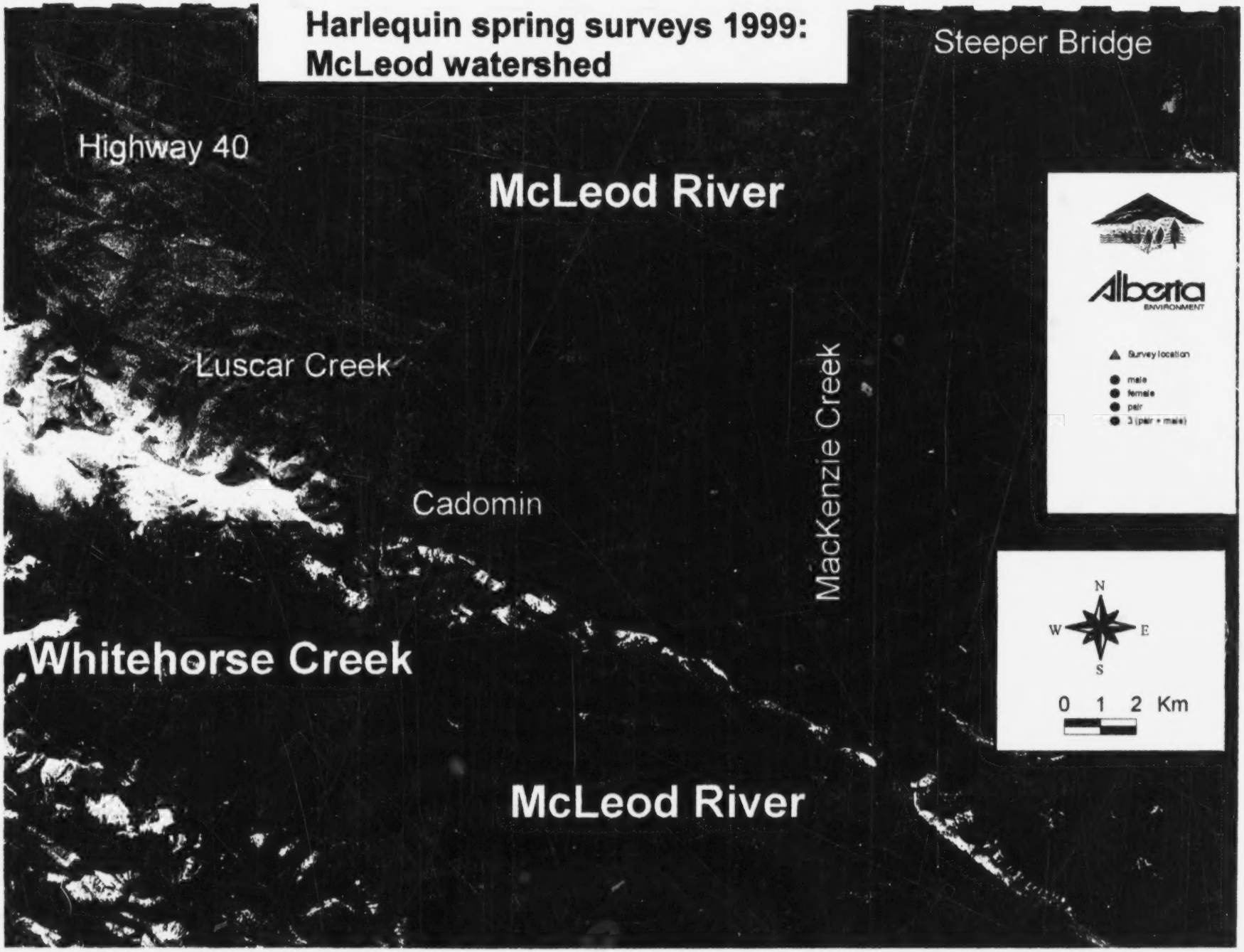
Harlequin duck spring survey 2000



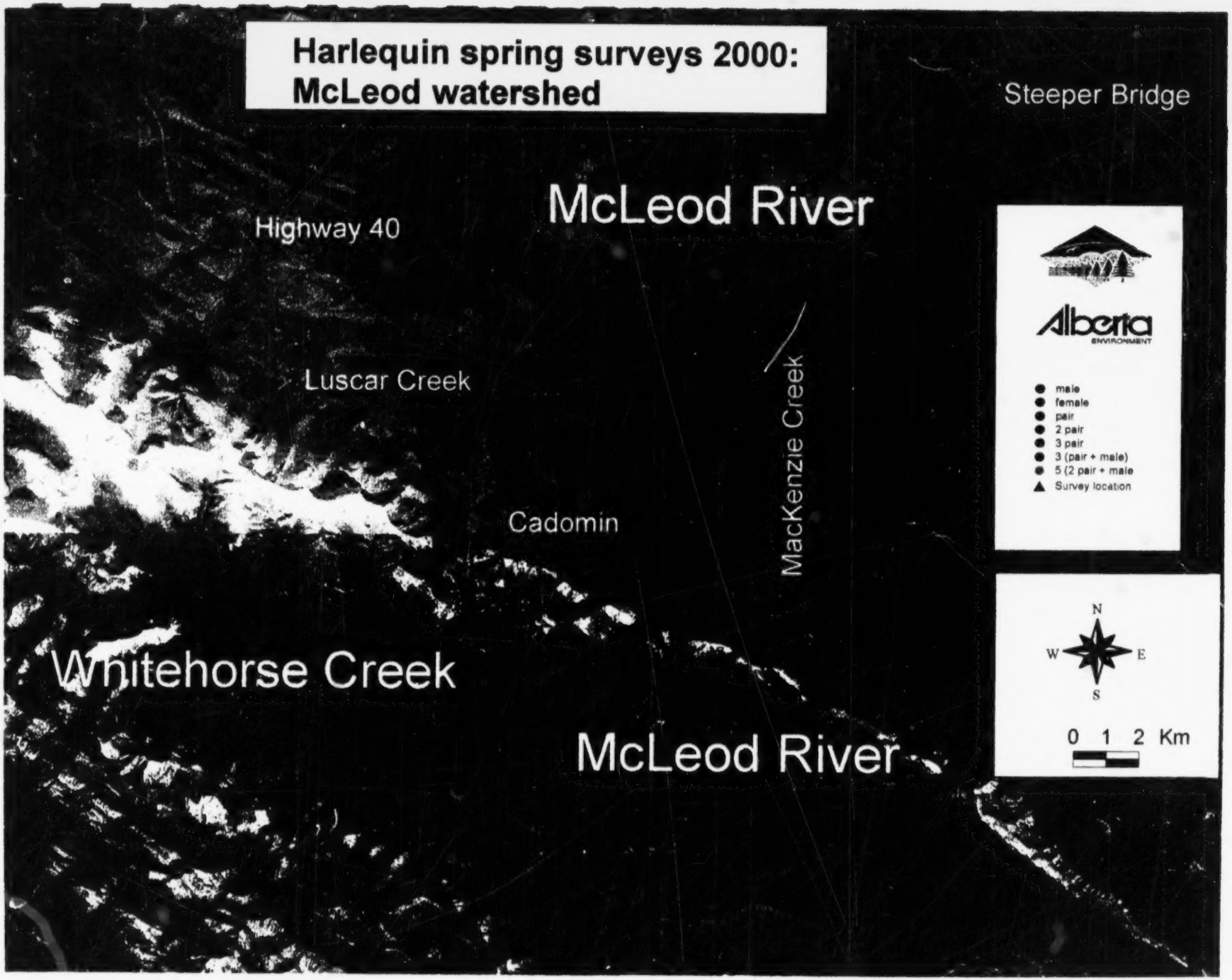
Appendix 4 - Harlequin spring surveys 1998:
McLeod watershed


Harlequin spring surveys 1998:
McLeod watershed
Highway 40
Steeper Bridge
McLeod River
Luscar Creek
MacKenzie Creek
Cadomin
Whitehorse Creek
McLeod River
Alberta
ENVIRONMENT
Survey locations
male
female
pair
N
W
E
S
0 1 2 Km

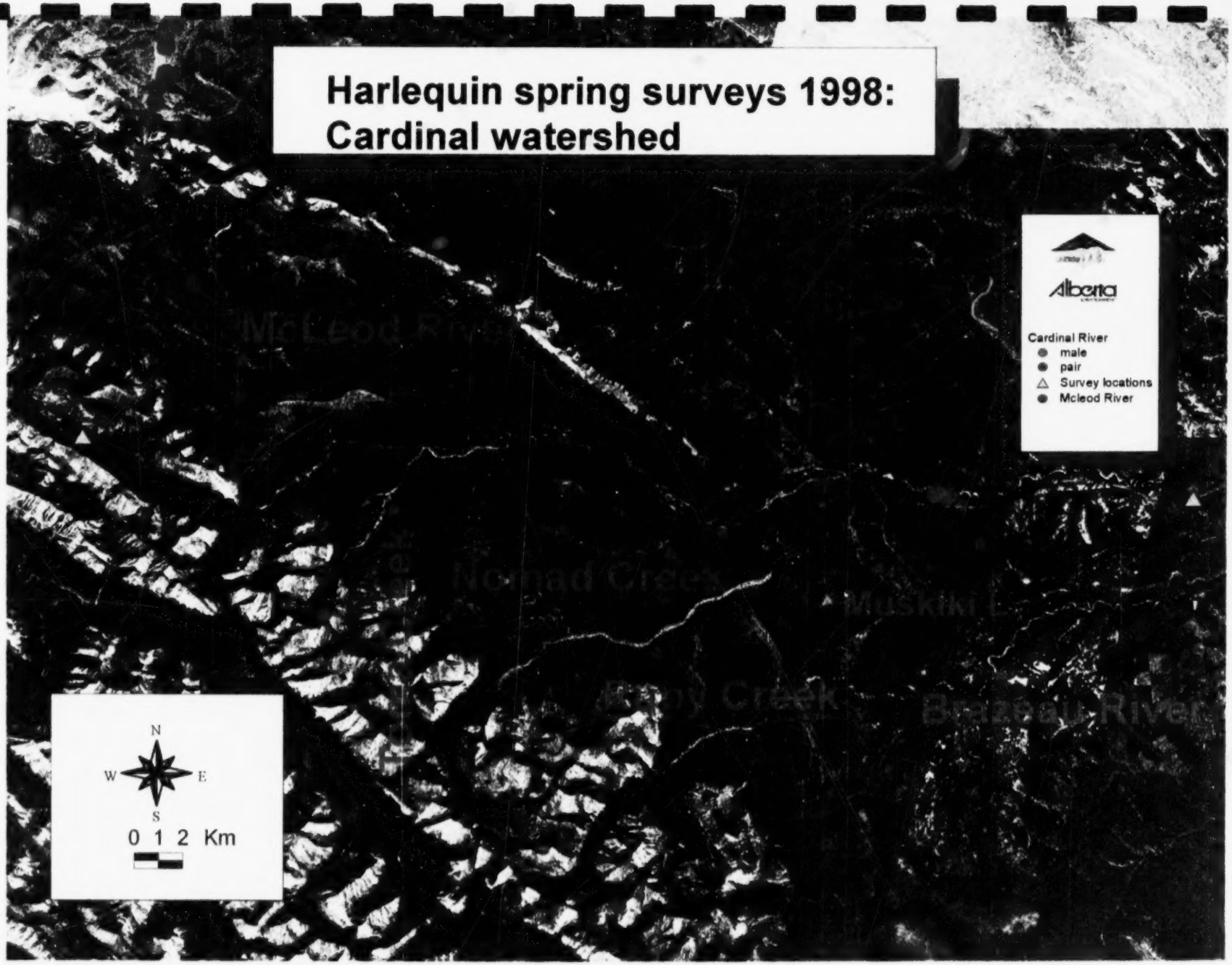
Appendix 5 - Harlequin spring surveys 1999: McLeod watershed


Harlequin spring surveys 1999:
McLeod watershed
Steeper Bridge
Highway 40
McLeod River
Luscar Creek
MacKenzie Creek
Cadomin
Whitehorse Creek
McLeod River
Alberta
ENVIRONMENT
Survey location
male
female
pair
3 (pair + male)
N
W
E
S
0 1 2 Km

Appendix 6 - Harlequin spring surveys 2000:
McLeod watershed

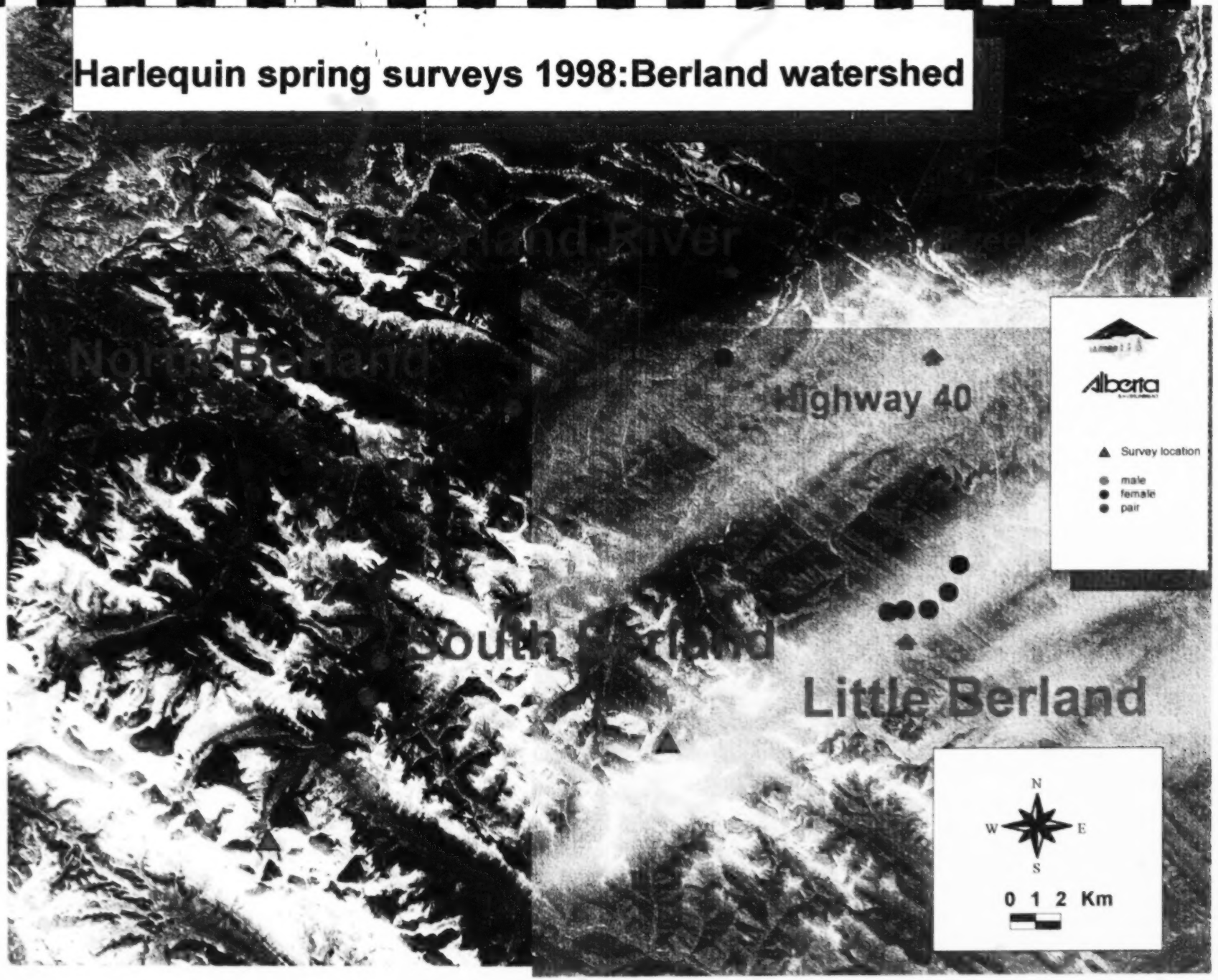

Harlequin spring surveys 2000:
McLeod watershed
Steeper Bridge
McLeod River
Highway 40
Luscar Creek
MacKenzie Creek
Cadomin
Whitehorse Creek
McLeod River
Alberta
ENVIRONMENT
male
female
pair
2 pair
3 pair
3 (pair + male)
5 (2 pair + male
Survey location
N
W
E
S
0 1 2 Km

Appendix 7 - Harlequin spring surveys 1998:
Cardinal watershed


Harlequin spring surveys 1998:
Cardinal watershed
Alberta
Cardinal River
male
pair
Survey locations
Mcleod River
N
W
E
S
0 1 2 Km

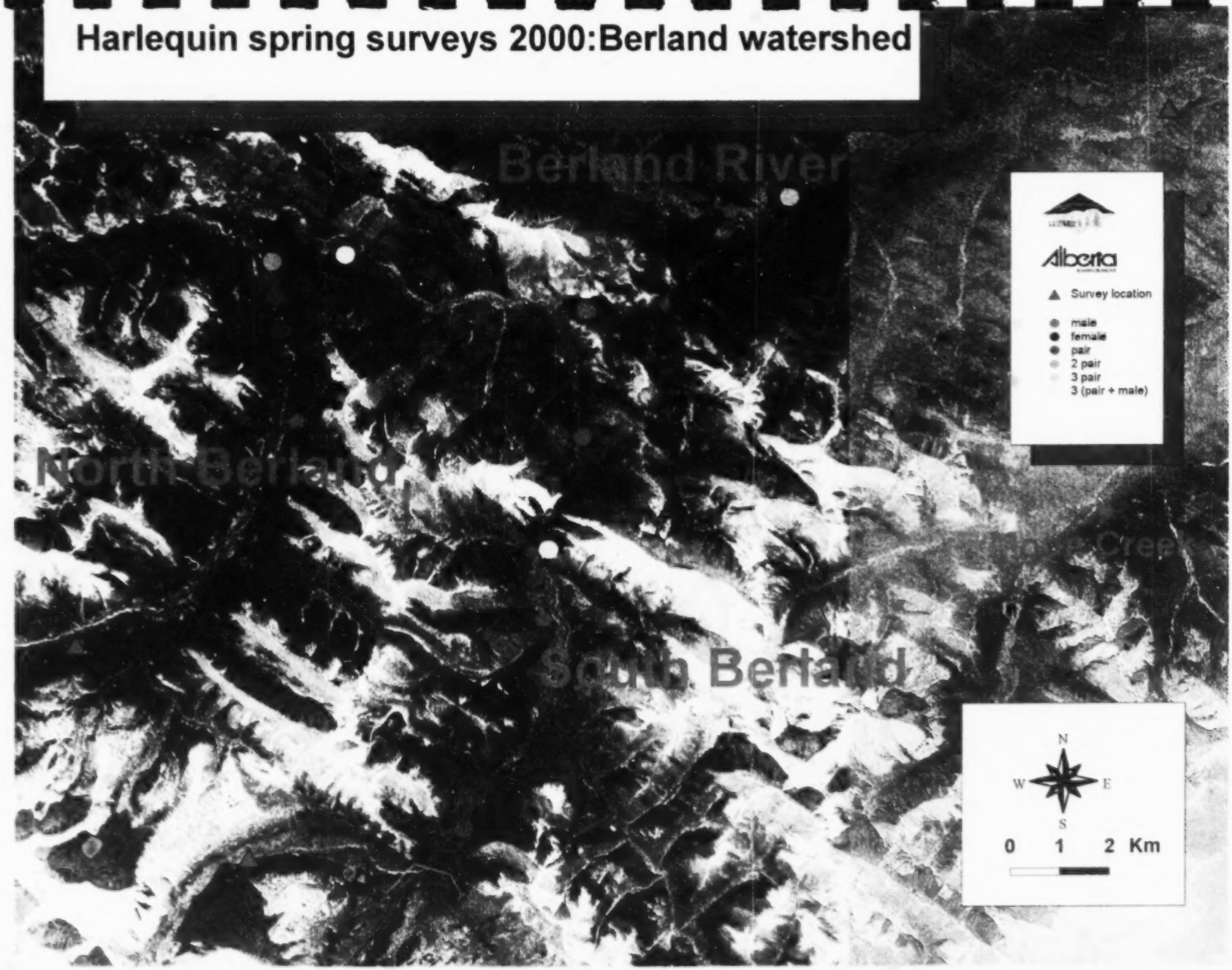
Appendix 8 - Harlequin spring surveys 1998: Berland watershed

Harlequin spring surveys 1998:Berland watershed

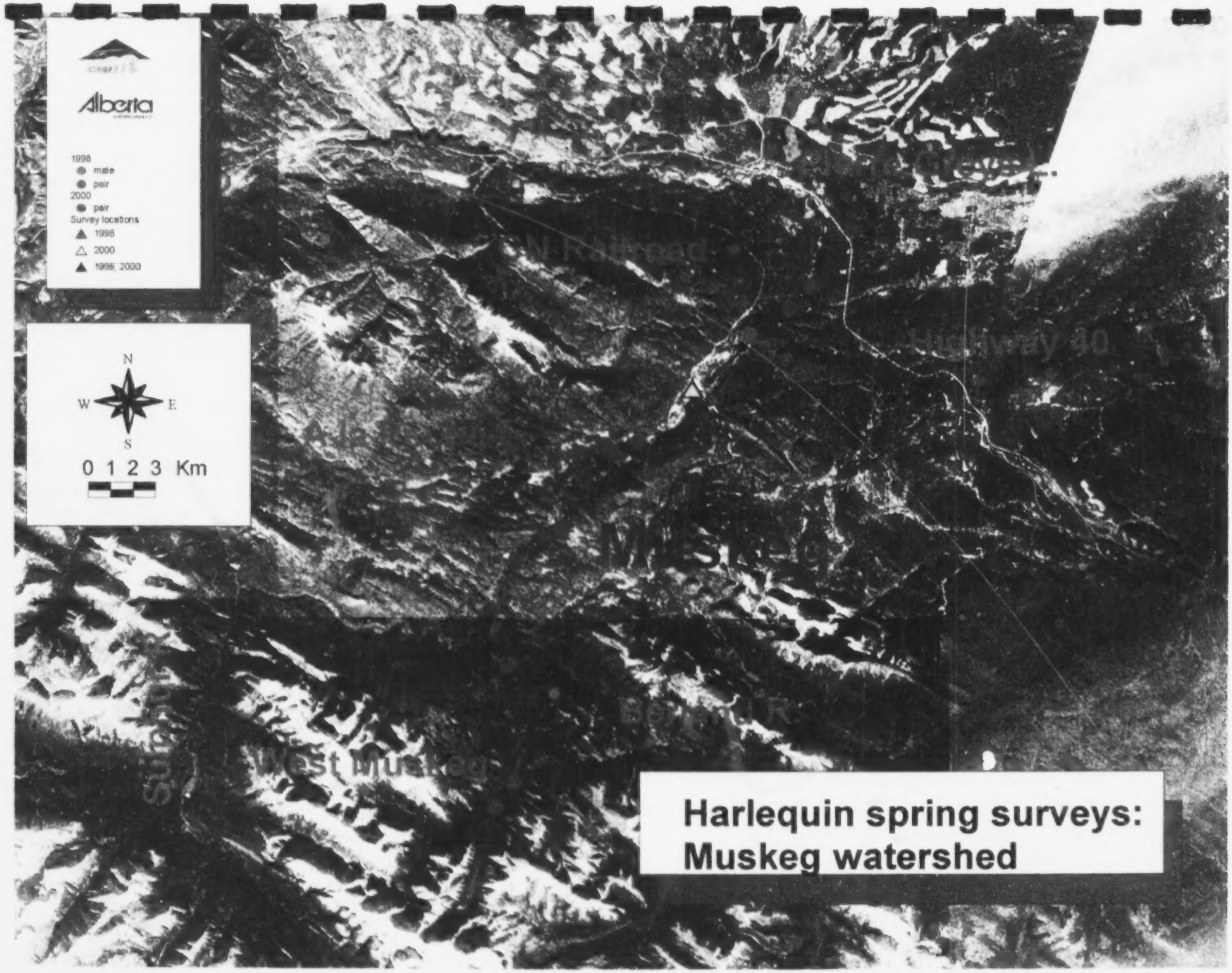


Appendix 9 - Harlequin spring surveys 2000: Berland watershed

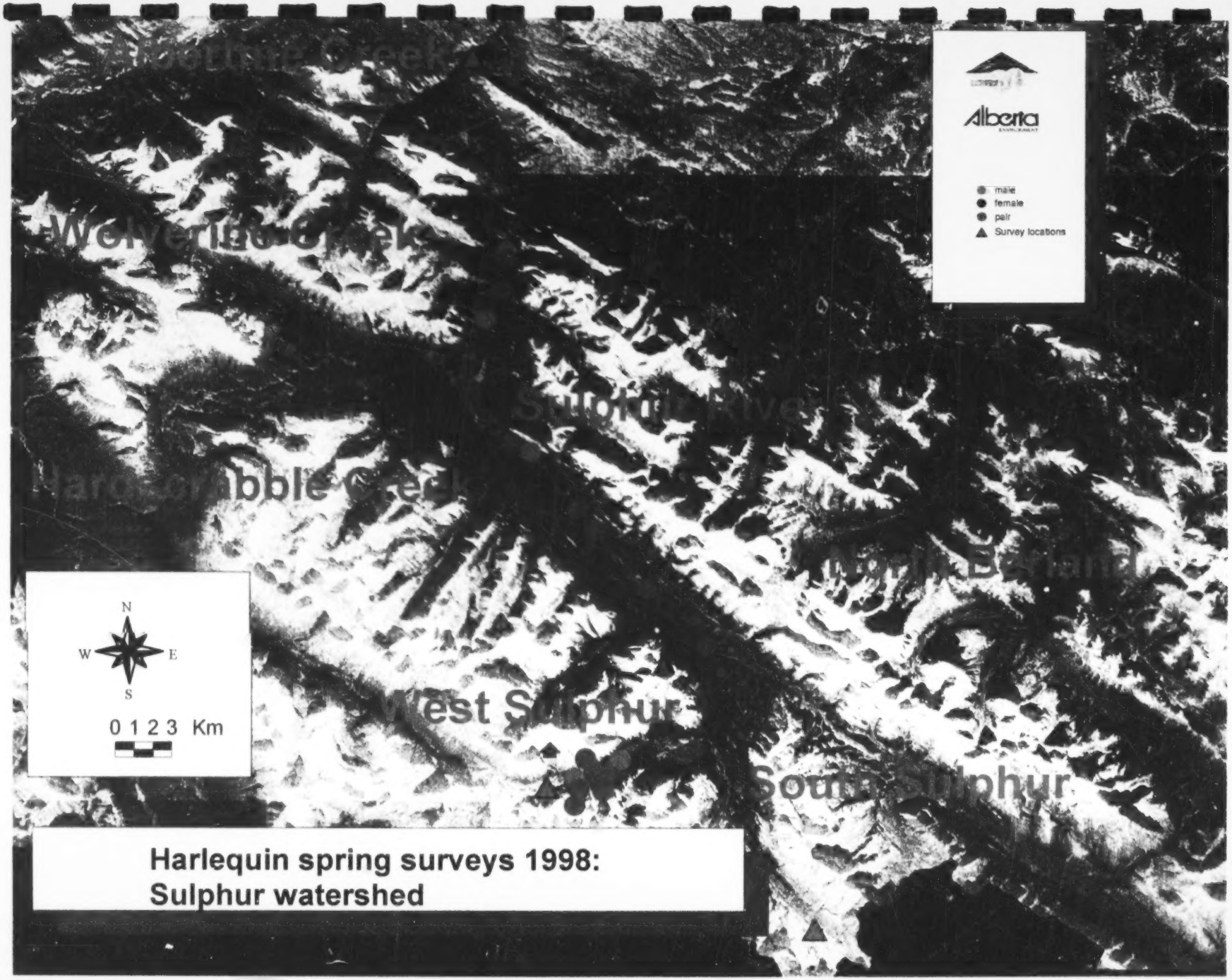
Harlequin spring surveys 2000:Berland watershed



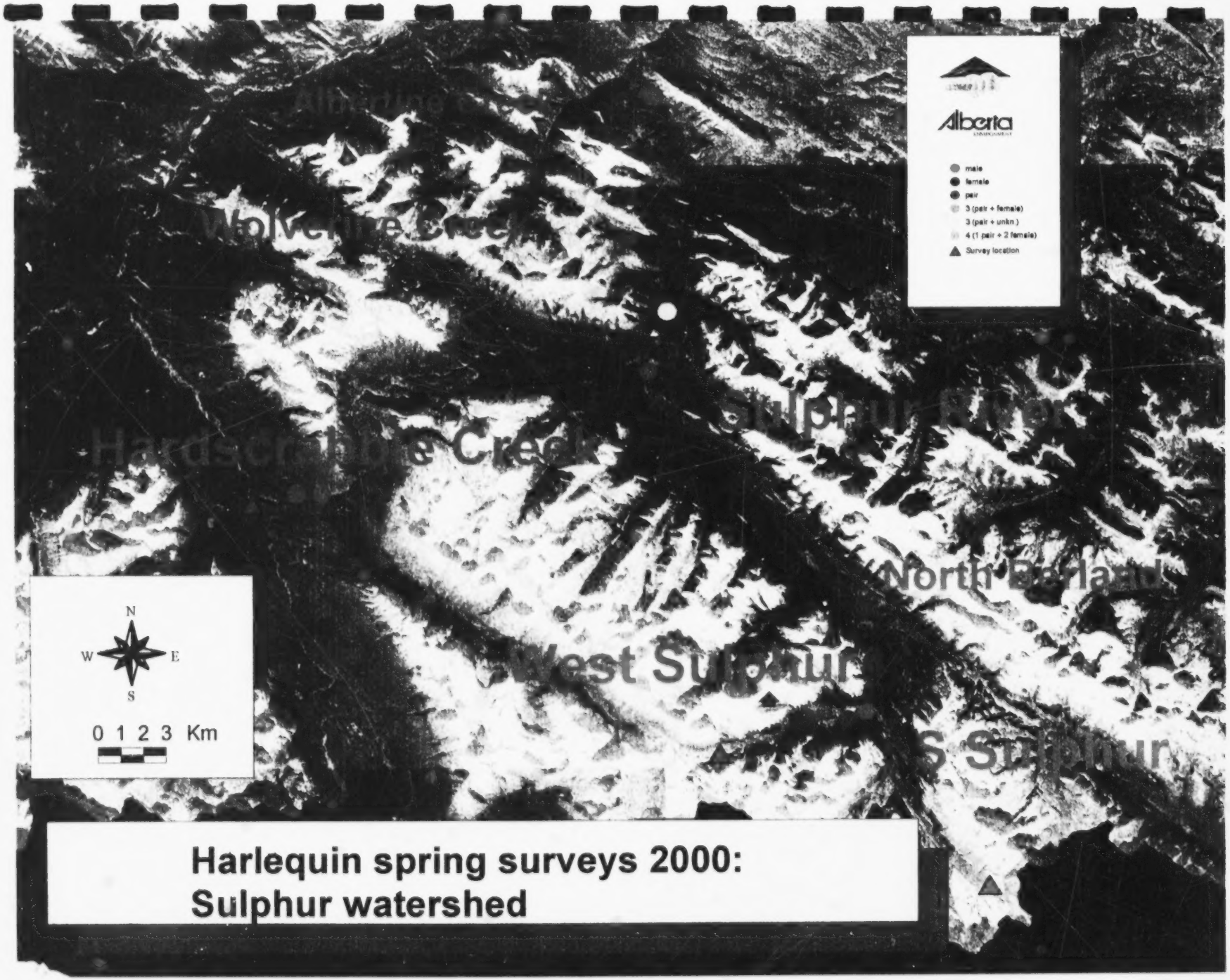
Appendix 10 - Harlequin spring surveys:
Muskeg watershed


Alberta
1998
male
pair
2000
pair
Survey locations
1998
2000
1998, 2000
N
W
E
S
0 1 2 3 Km
Harlequin spring surveys:
Muskeg watershed

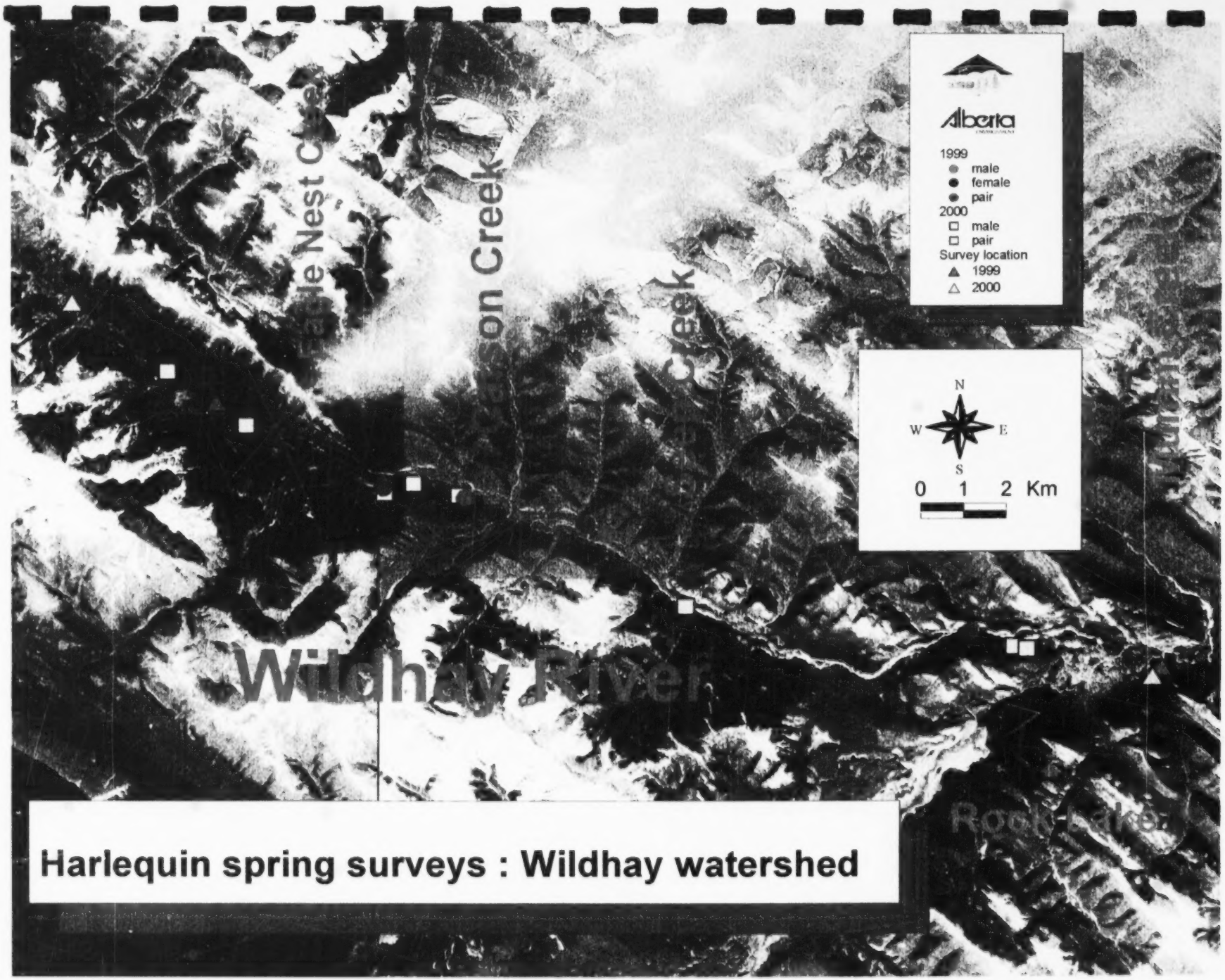
Appendix 11 - Harlequin spring surveys 1998
Sulphur watershed


Alberta
male
female
pair
Survey locations
N
W
E
S
0 1 2 3 Km
West Sulphur
Harlequin spring surveys 1998:
Sulphur watershed

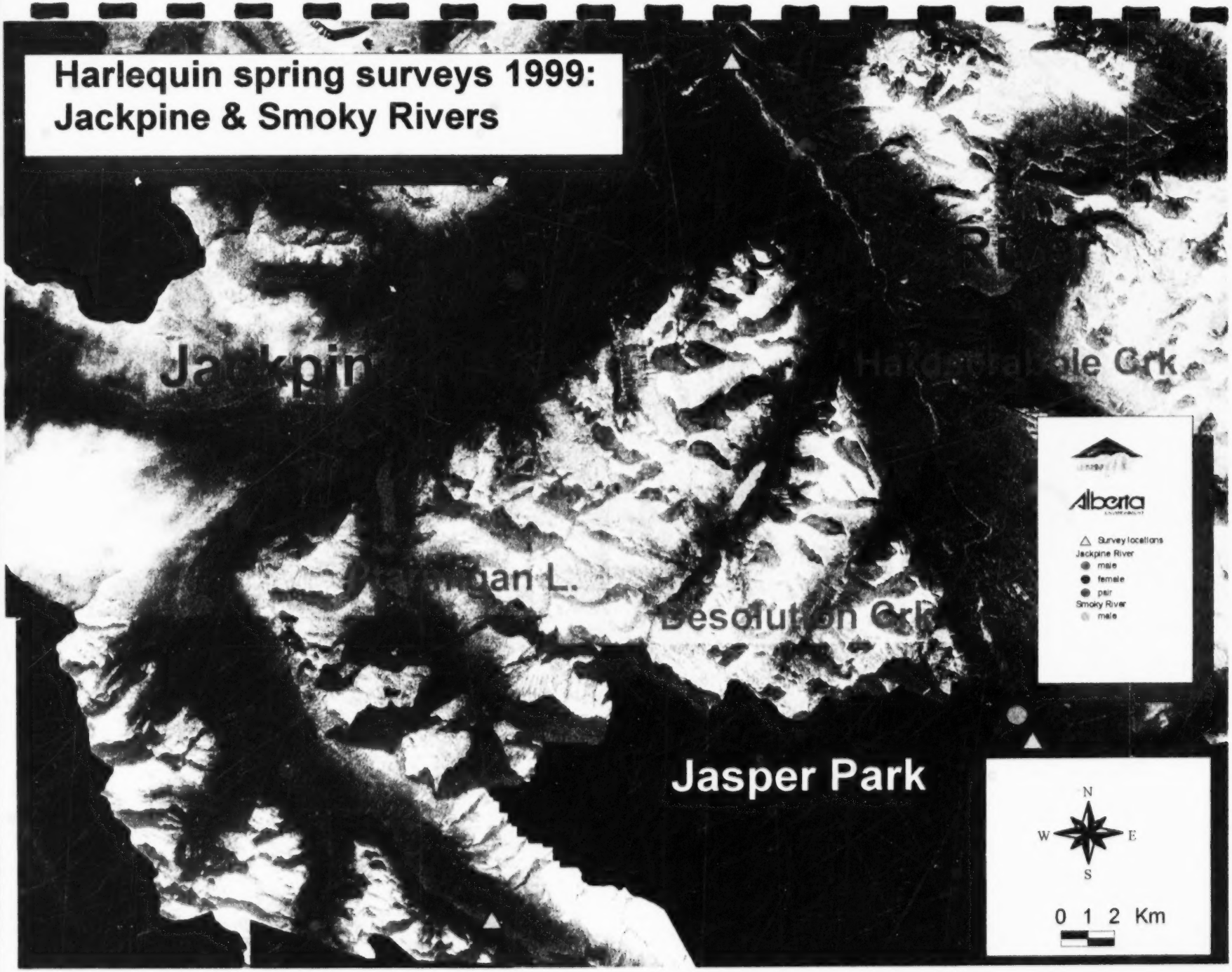
Appendix 12 - Harlequin spring surveys 2000:
Sulphur watershed


Alberta
male
female
pair
3 (pair + female)
3 (pair + unkn.)
4 (1 pair + 2 female)
Survey location
N
W
E
S
0 1 2 3 Km
Harlequin spring surveys 2000:
Sulphur watershed

Appendix 13 - Harlequin spring surveys
Wildhay watershed

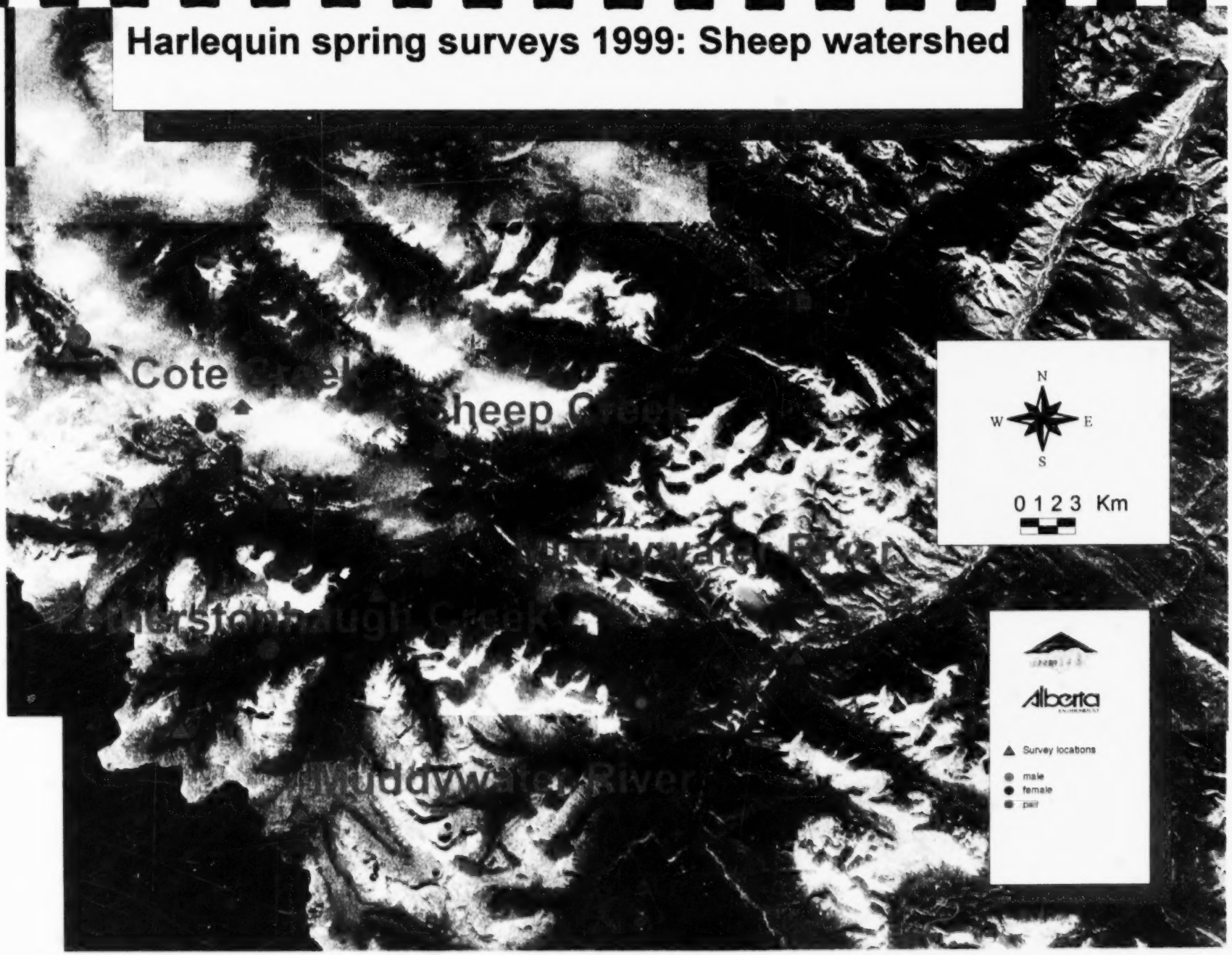

Alberta
1999
male
female
pair
2000
male
pair
Survey location
1999
2000
N
W
E
S
0 1 2 Km
Wildhay River
Harlequin spring surveys : Wildhay watershed

Appendix 14 - Harlequin spring surveys 1999: Jackpine & Smoky Rivers

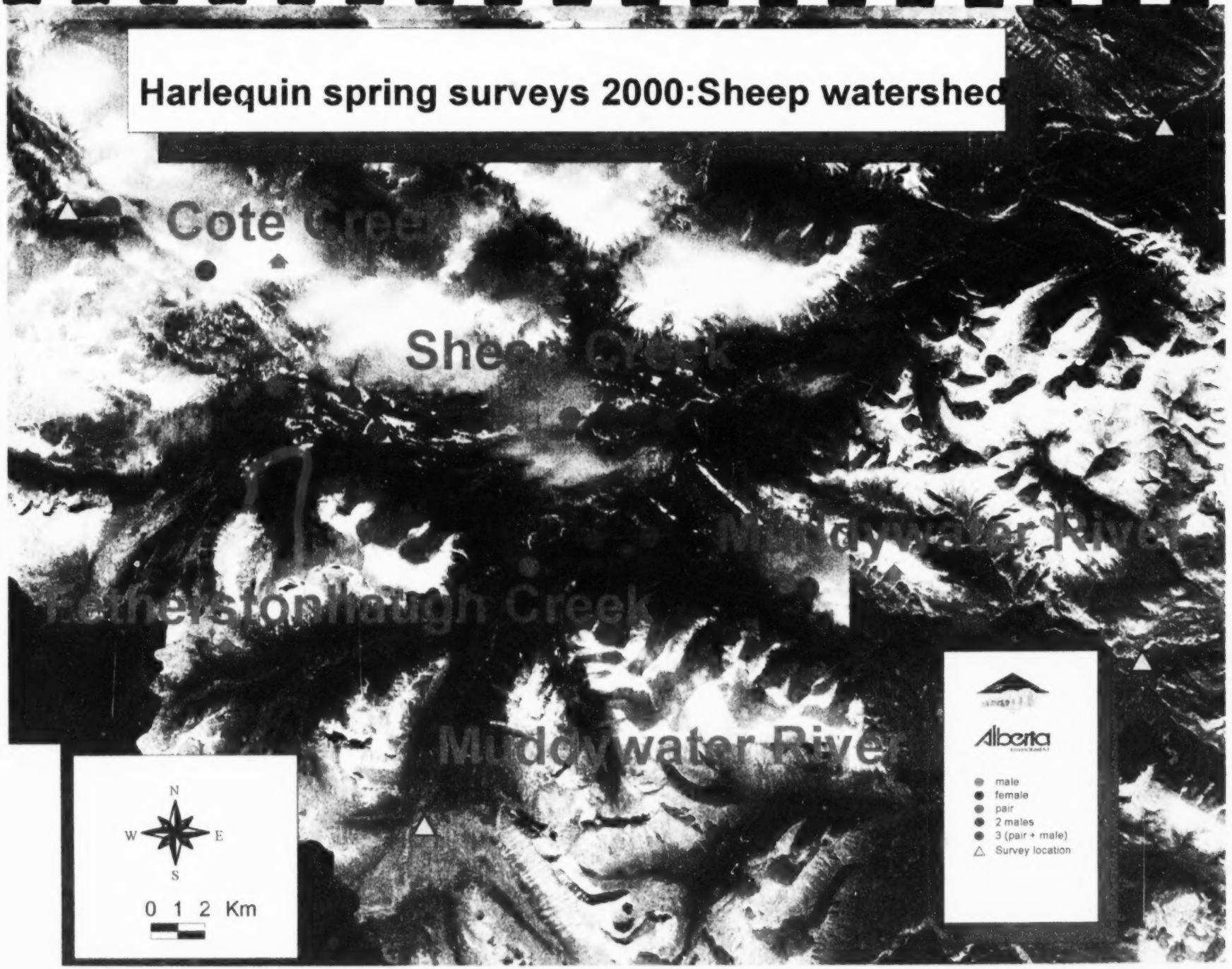

Harlequin spring surveys 1999:
Jackpine & Smoky Rivers
Jackpin
Hay
ale Crk
an L.
Desolation Crk
Jasper Park
Alberta
Survey locations
Jackpine River
male
female
pair
Smoky River
male
N
W
E
S
0 1 2 Km

Appendix 15 - Harlequin spring surveys 1999:
Sheep watershed

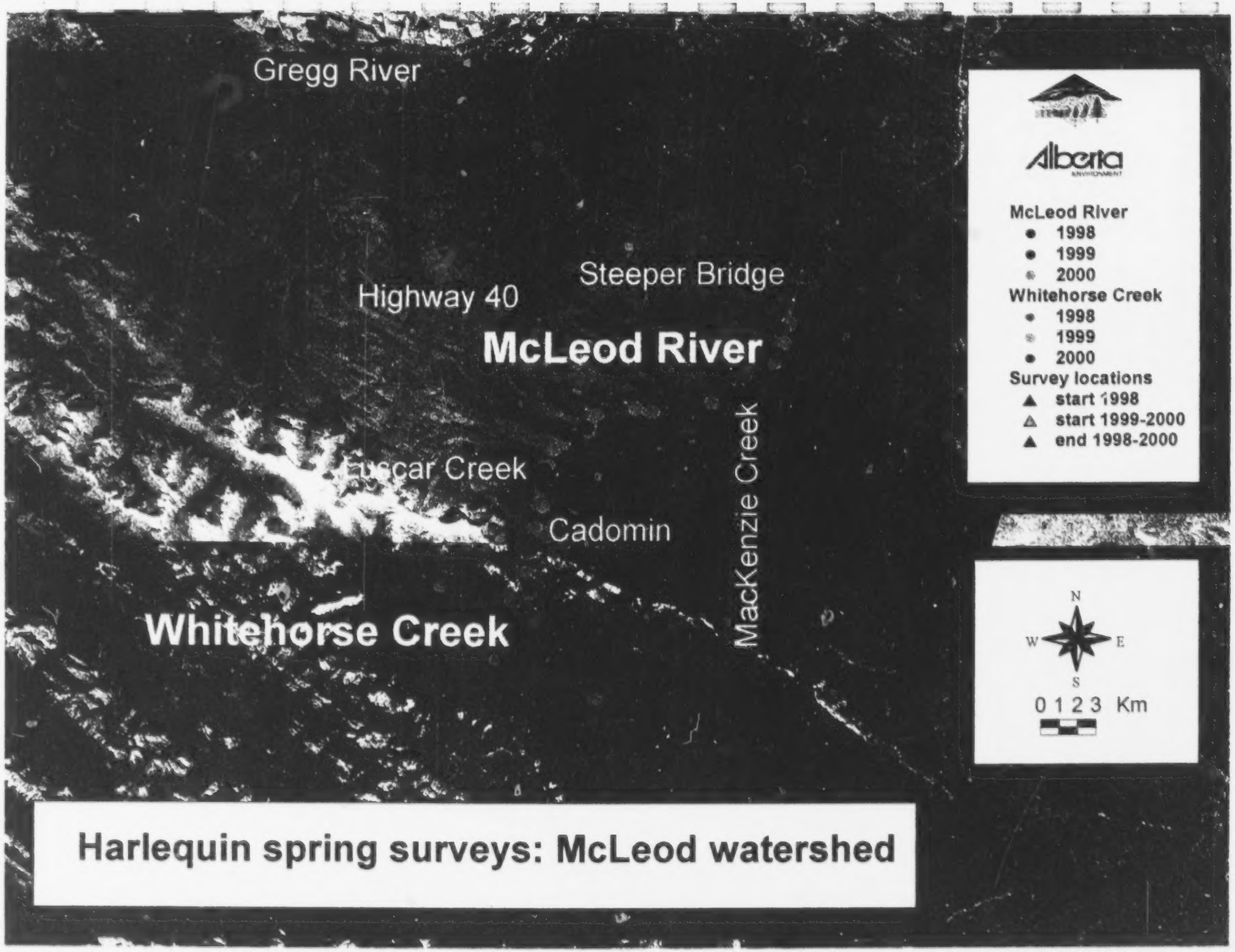
Harlequin spring surveys 1999: Sheep watershed



Appendix 16 - Harlequin spring surveys 2000: Sheep watershed

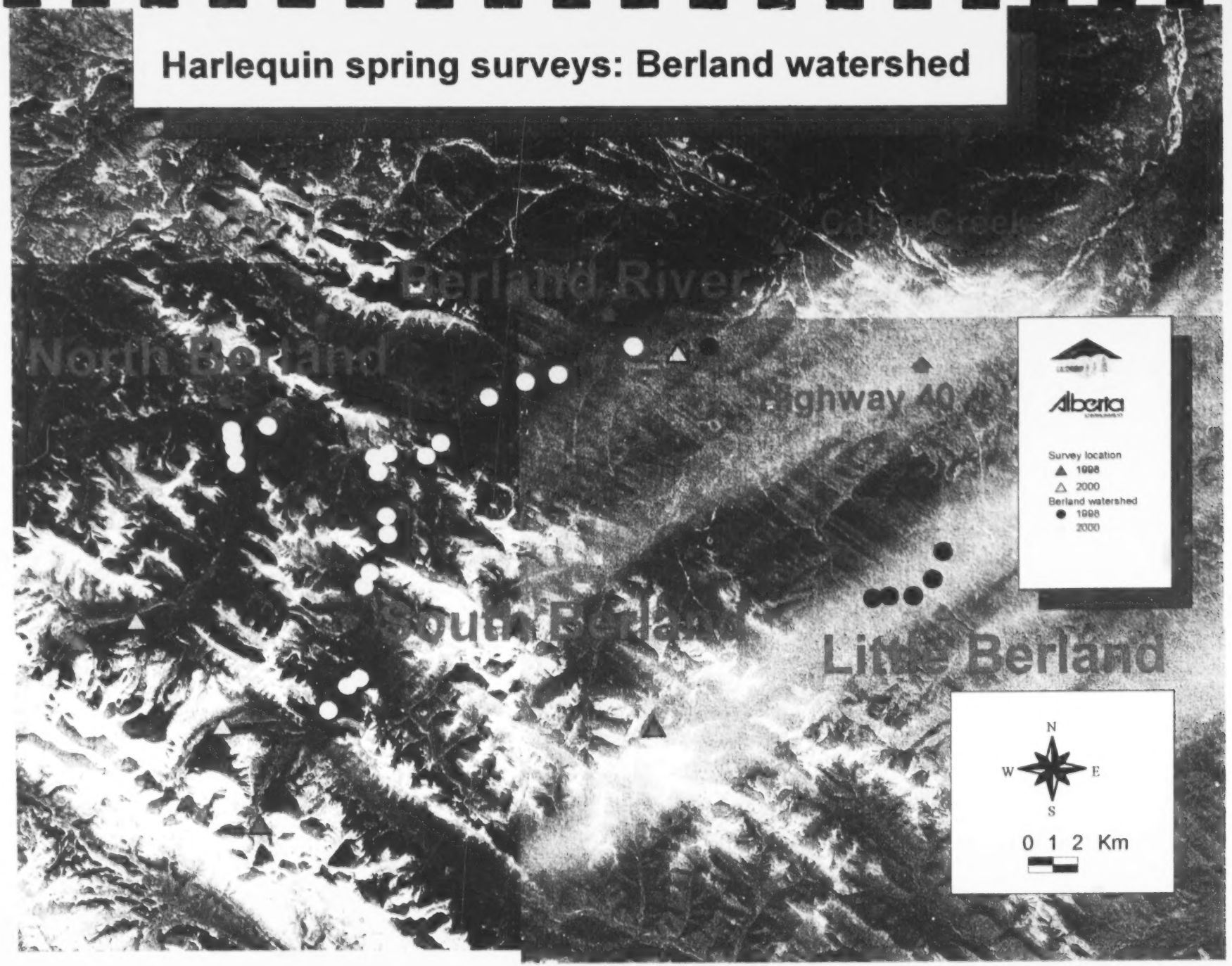

Harlequin spring surveys 2000:Sheep watershed
Cote Creek
Sheep Creek
Muddywater River
Muddywater River
N
W
E
S
0 1 2 Km
Alberta
male
female
pair
2 males
3 (pair + male)
Survey location

Appendix 17 - Harlequin spring surveys:
McLeod watershed

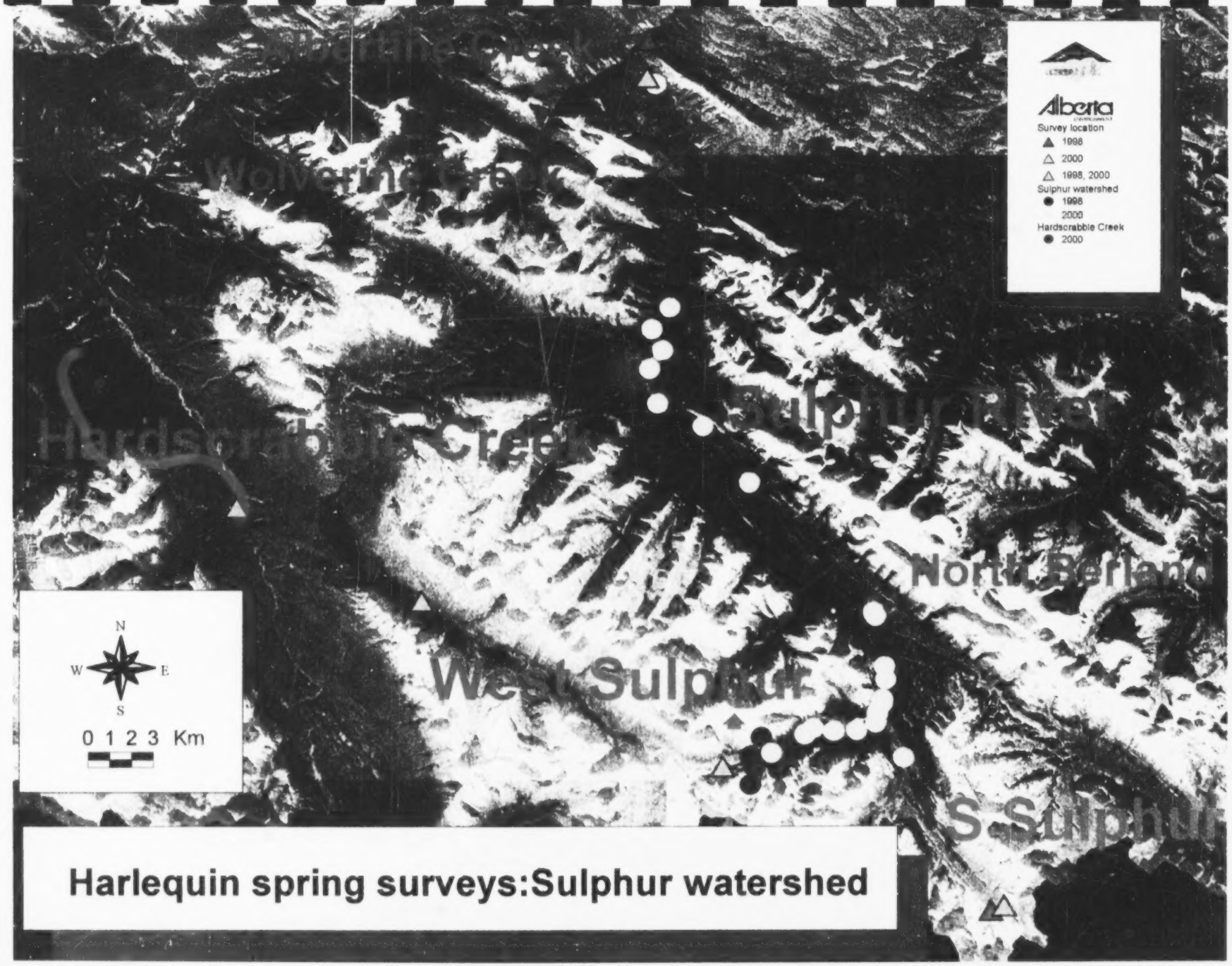


Harlequin spring surveys: McLeod watershed

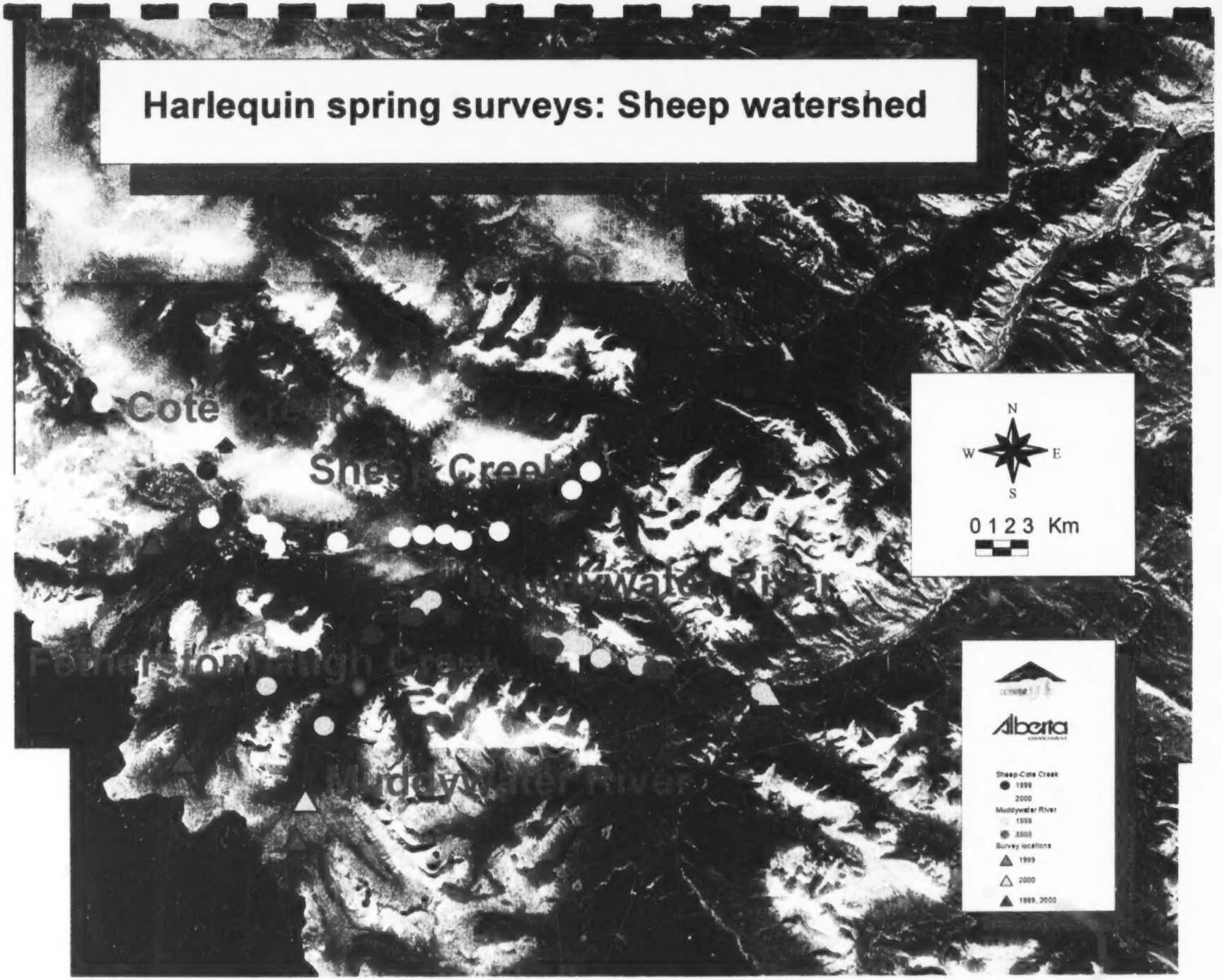
Appendix 18 - Harlequin spring surveys: Berland watershed


Harlequin spring surveys: Berland watershed
Berland River
North Berland
Highway 40
South Berland
Little Berland
Alberta
Survey location
1998
2000
Berland watershed
1998
2000
N
W
E
S
0 1 2 Km

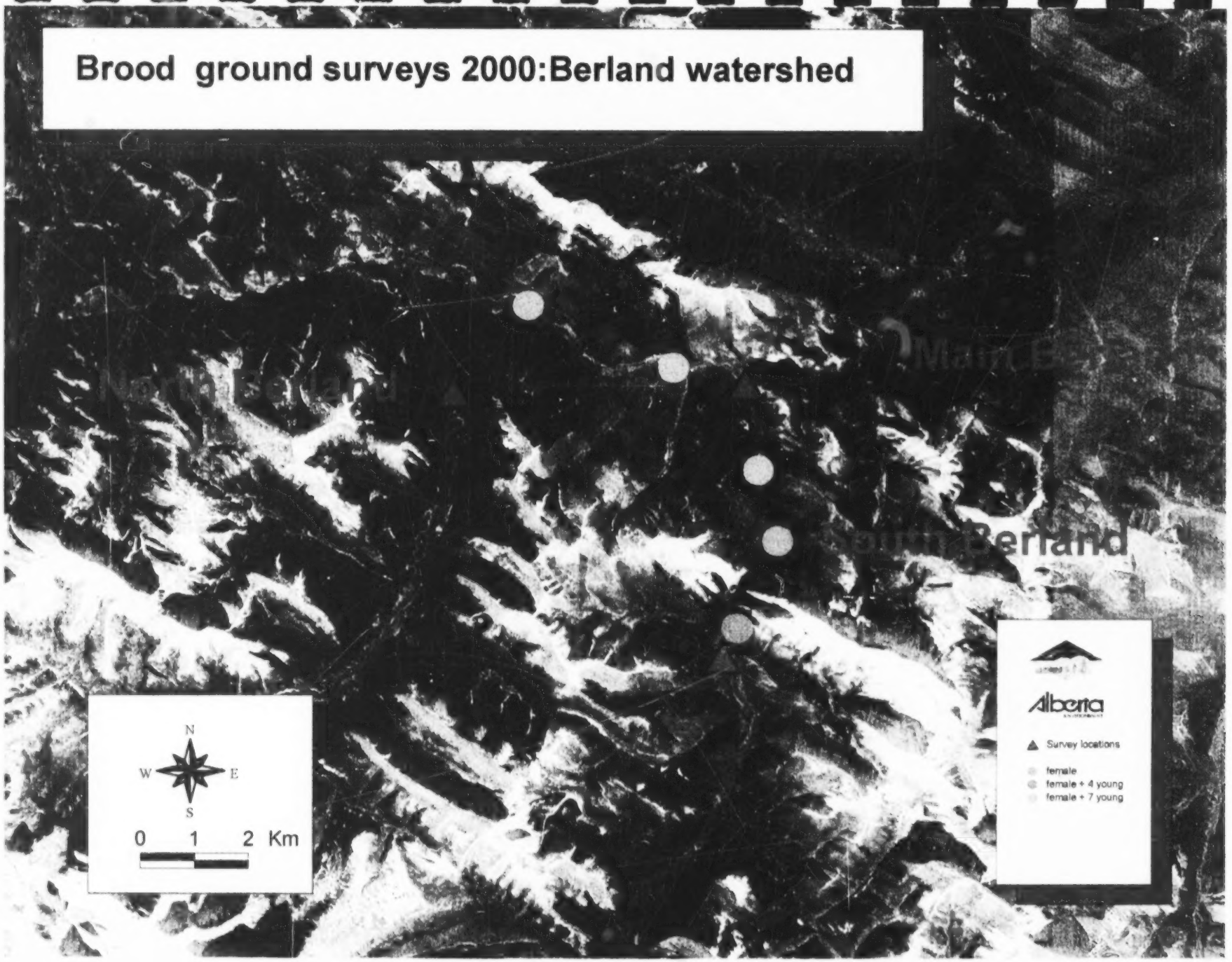
Appendix 19 - Harlequin spring surveys:
Sulphur watershed


Alberta
Survey location
1998
2000
1998, 2000
Sulphur watershed
1998
2000
Hardscrabble Creek
2000
N
W
E
S
0 1 2 3 Km
Harlequin spring surveys:Sulphur watershed

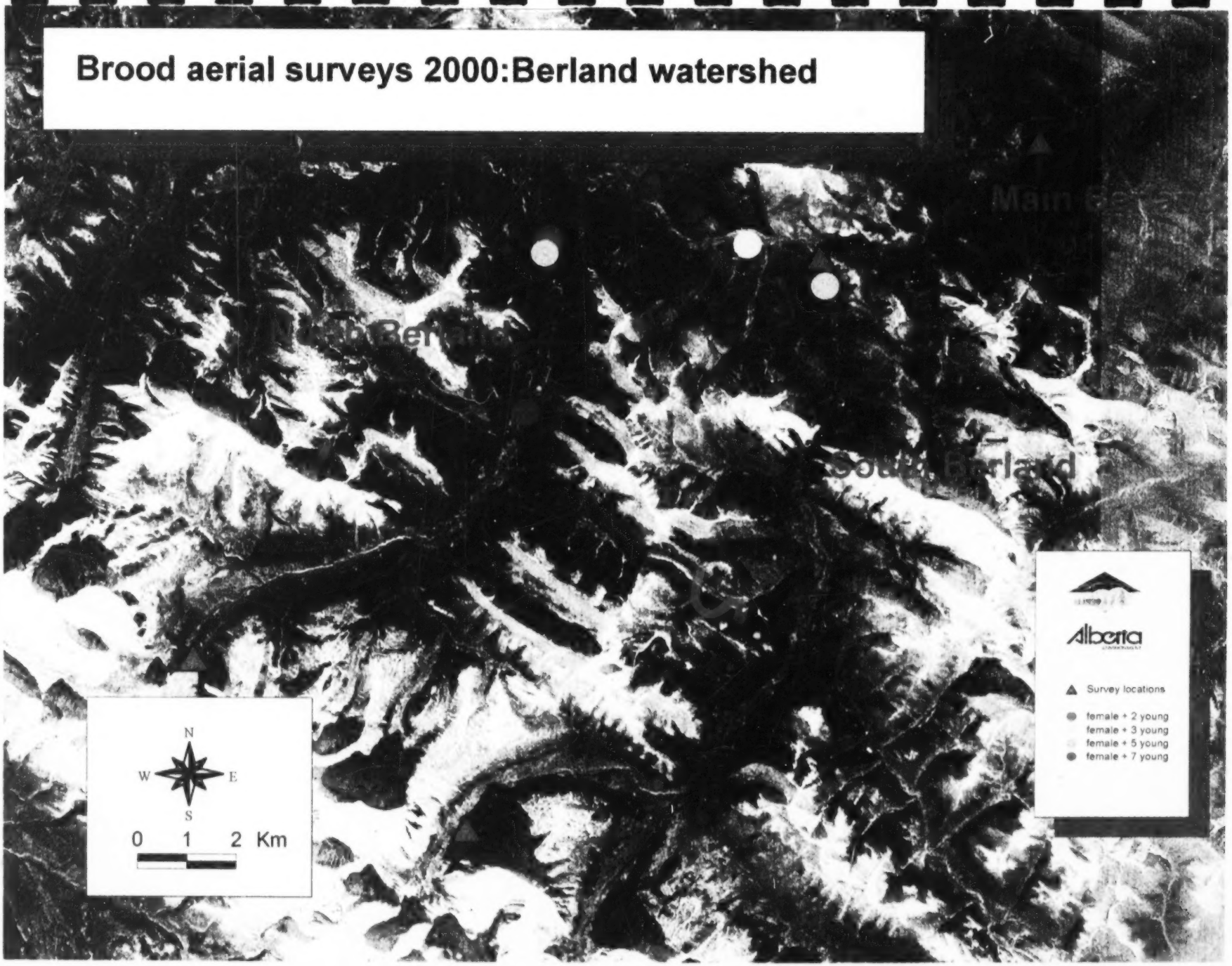
Appendix 20 - Harlequin spring surveys:
Sheep watershed


Harlequin spring surveys: Sheep watershed
Cote
Sheep Creek
N
W
E
S
0 1 2 3 Km
Alberta
Sheep-Cote Creek
1999
2000
Muddywater River
1999
2000
Survey locations
1999
2000
1999, 2000

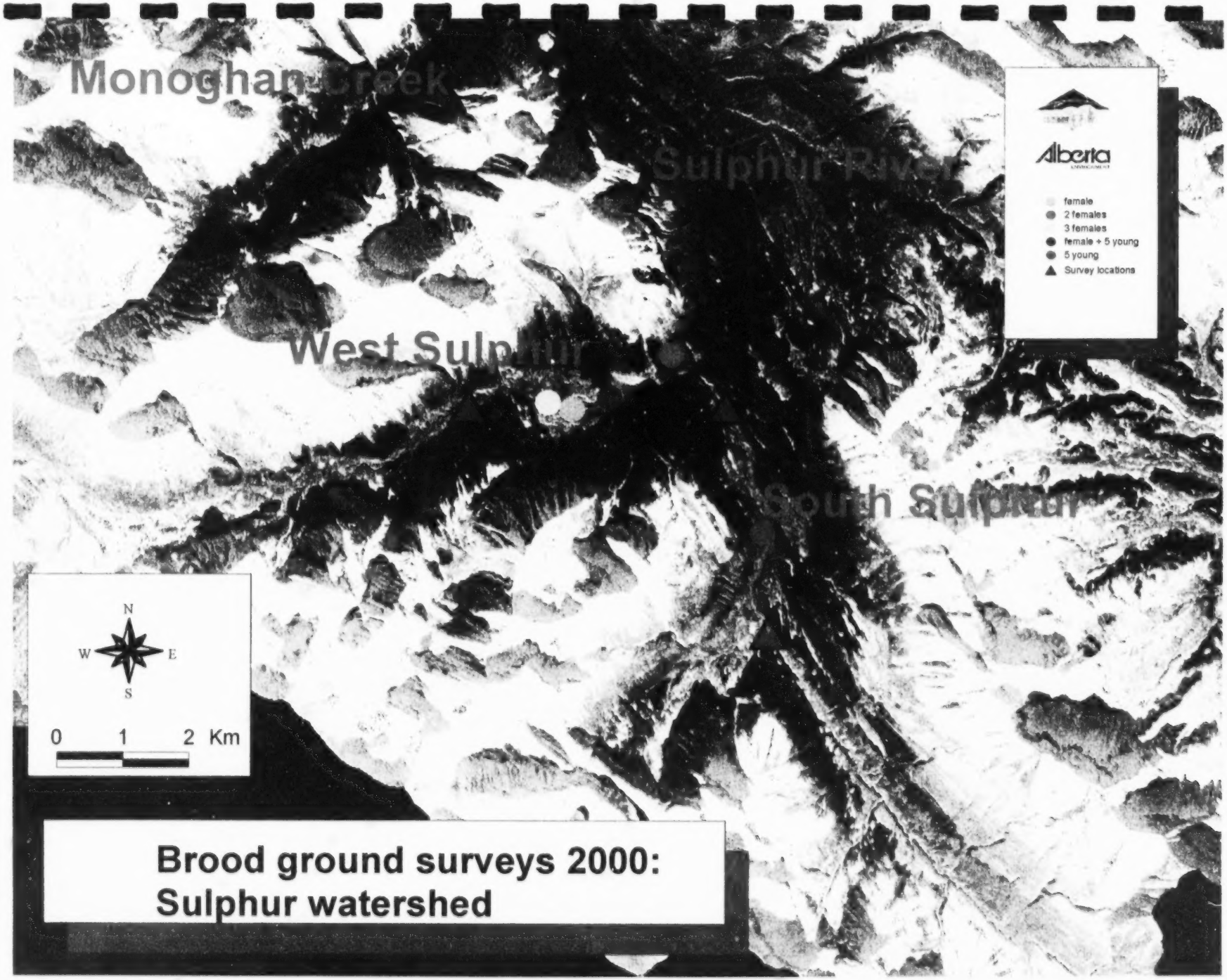
Appendix 21 - Brood ground surveys 2000:
Berland watershed


Brood ground surveys 2000:Berland watershed
North Berland
South Berland
N
W
E
S
0 1 2 Km
Alberta
Survey locations
female
female + 4 young
female + 7 young

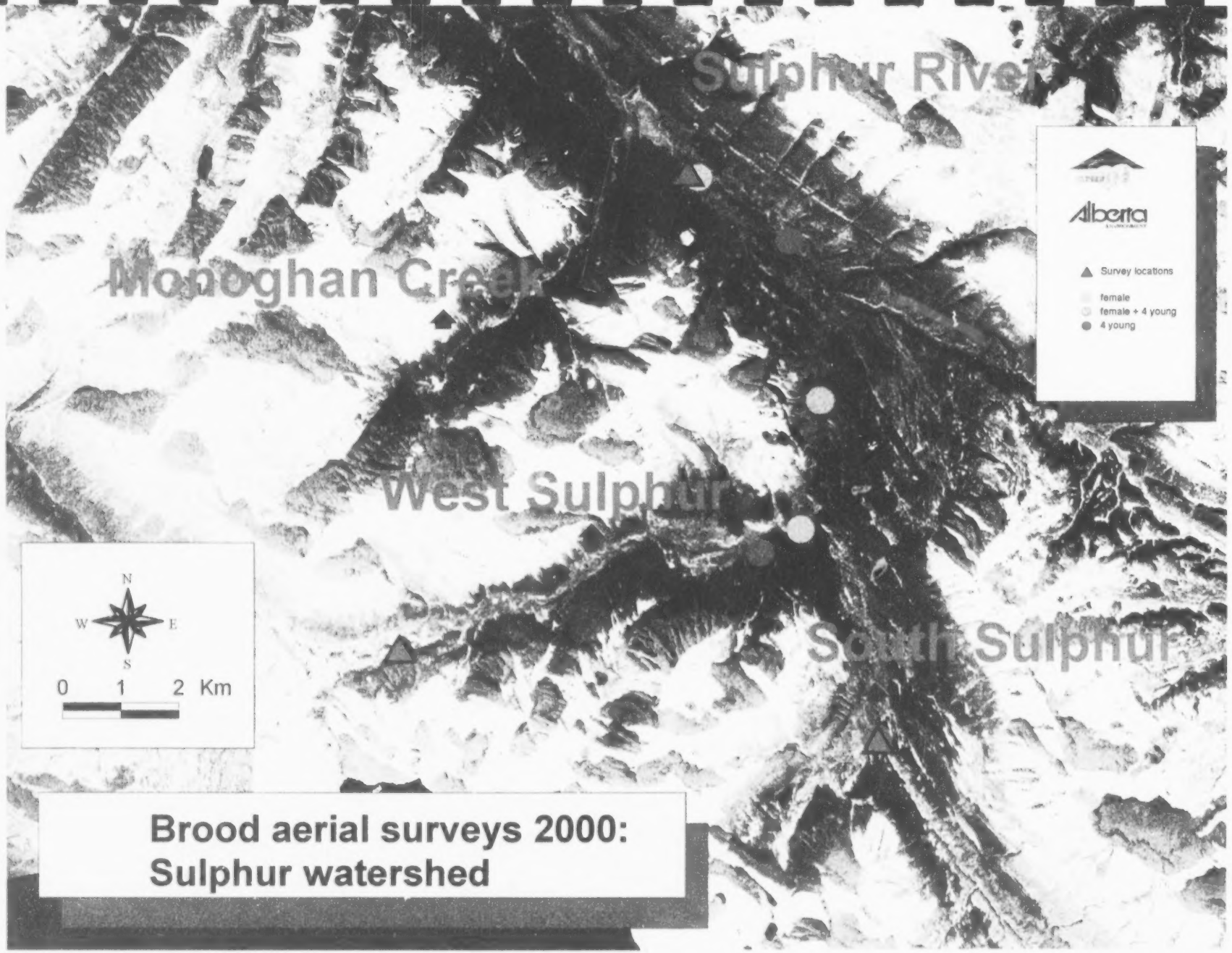
Appendix 22 - Brood aerial surveys 2000:
Berland watershed


Brood aerial surveys 2000:Berland watershed
Alberta
Survey locations
female + 2 young
female + 3 young
female + 5 young
female + 7 young
N
W
E
S
0 1 2 Km

Appendix 23 - Brood ground surveys 2000:
Sulphur watershed


Monoghan Creek
Sulphur River
West Sulphur
South Sulphur
Alberta
female
2 females
3 females
female + 5 young
5 young
Survey locations
N
W
E
S
0 1 2 Km
Brood ground surveys 2000:
Sulphur watershed

Appendix 24 - Brood aerial surveys 2000:
Sulphur watershed



Brood aerial surveys 2000:
Sulphur watershed